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DETERMINATION OF TRACE SILVER IN FARO ORE

S.L. Chryssoulis
Surface Science Western

J.M.D. Wilson
Mineral Processing Laboratory

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DETERMINATION OF TRACE SILVER IN FARO ORE

by

Stephen L. Chryssoulis* and John M.D. Wilson**

ABSTRACT

The "invisible" silver concentration of the major sulphide minerals in the Faro ore was determined by ion microprobe analysis. Marcasite, chalcopyrite and sphalerite carry silver in significant amounts, while pyrite has only trace amounts of silver. The average silver content of marcasite is 61.5±42 ppmw, of chalcopyrite 35.±10 ppmw, and of sphalerite, 21.2±6.4 ppmw. Marcasite is an important constituent of the final tailings. Based on the limited number of pyrite grains analyzed, it appears that pyrite in the zinc concentrate is more silver-rich compared to pyrite in the final tailings. However, more analysis would be required to confirm this observation.

Keywords: Faro, lead-zinc ore, trace elements, silver, SIMS

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*Process Mineralogy Section, Surface Science Western and ** Mineral Processing Laboratory, Mineral Sciences Laboratories, CANMET, Energy, Mines and Resources Canada.

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BACKGROUND AND OBJECTIVES

CANMET requested the quantification of silver distributed in the crystal structure of the major sulphide minerals in the Faro ore (Yukon Territory), using Secondary Ion Mass Spectrometry (SIMS). The objective of this work was outlined during discussions with Mr. John Wilson, the scientific authority of the project, and is summarized as follows:

(i) Implant Faro samples with ^{107}Ag for calibrating the SIMS.

(ii) Determine quantitatively the silver content of pyrite, sphalerite and chalcopyrite of Faro.

Three samples of Faro mill products were received in October 1989. They were of the zinc concentrate, lead concentrate and the final tailings. An additional tailings sample was sent in June 1990 because the first had very few sulphide grains suitable for SIMS analysis.

The laboratory work included preparation of the last sample, ion implantation (^{107}Ag), optical microscopy to select grains for SIMS, and the ion probe microanalysis.

ANALYTICAL

The ion microprobe (SIMS) was used to quantify the silver content of sphalerite, pyrite and chalcopyrite grains in samples from the Brunswick mill in 1985 (Chryssoulis & Surges, 1988) and then in samples of Zinc Hindustan in 1988 (Chryssoulis, 1988). For quantitative results, calibration can be achieved using internal standards produced by ion implantation or, by means of mineral specific calibration curves (Chryssoulis et al., 1986; Chryssoulis, 1990). Isotopically pure

implants (^{107}Ag or ^{109}Ag) are required to decrease analysis time and improve on accuracy.

The typical area of analysis is 60 μm in diameter, therefore, mineral grains should be of that size or larger in order to be analyzed. Small grains can be analyzed using a 25 μm aperture with loss in sensitivity. The minimum detection limit (MDL) for Ag in pyrite, sphalerite and chalcopyrite is better than 0.2 ppmw (60 μm analysis area; counting time 10 seconds). The analysis time per grain is 10 - 12 minutes for implanted samples and 4 - 5 minutes when using external standardization (calibration curve). However, external standardization is less precise and accurate, especially in the case of sphalerite.

Ion probe microanalysis is a destructive microanalytical technique with successively deeper layers being analyzed with time. Therefore, hidden sub-micrometer silver inclusions can be distinguished. For the same reason, the grain mounts prepared for SIMS analyses must have some "bulk" conductivity which is provided by the admixed fine graphitic carbon. Surface conductivity is provided by carbon coating. Grain mounts with no carbon tend to charge excessively, making impossible the analysis, or they charge differentially, thus affecting the precision of the result.

Grains for SIMS analyses were preselected and marked under the optical microscope. Photographic "maps" of the grain mounts were used for locating the selected grains in the ion microprobe. Results were depicted graphically in the form of in-depth concentration profiles. Four isotopes were monitored, ^{56}Fe, ^{66}Zn, ^{107}Ag and ^{109}Ag. The implanted Ag isotope (^{107}Ag) had a counting time of 3 seconds while

the ^{109}Ag was monitored for 10 seconds to improve the MDL. Selected typical SIMS data outputs are given in Appendix A1.

DISCUSSION OF RESULTS

A total of 93 sulphide grains were analyzed by SIMS, of which 57 were sphalerite grains, 21 were pyrite, 12 were marcasite and 3 were chalcopyrite grains. Results are tabulated in Tables 1 and 2.

The Faro sphalerite has an average silver content of 21.2 parts per million weight (ppmw). The confidence interval of the average at the 95% significance levels is 6.4 ppmw. The highest reported concentration was 152 ppmw (with no evidence of silver mineral microinclusions), and the minimum, 2.9 ppmw (see Figure 1). Typical depth profiles in sphalerite grains implanted with ^{107}Ag are given in Appendix A1.

The average Ag concentration in 20 pyrite grains was 1.6±1.1 ppmw. The 8 pyrite grains from the Zn concentrate had significantly higher Ag, 3.7±2.1 ppmw, compared to 0.13±0.08 ppmw for 12 pyrites from the tailings (see Figure 2). The difference seems to be statistically significant. However, arriving to the conclusion that traces of Ag within the pyrite caused pyrite activation leading to the contamination of Zn concentrate, would require more data.

Marcasite is an important constituent of the ore and the final tailings. The average Ag content of 12 marcasite grains is 61.5±42. ppmw, which is considerably higher than that of pyrite. Even by not taking into consideration the two marcasite grains with the highest Ag contents (295. and 116. ppmw As), the range of the Ag

content of the remaining marcasite is different from that of the Ag in pyrite (see Figure 2).

Three chalcopyrite grains from Faro had an average Ag content of 35.±10. ppmw which is closely comparable to that of the marcasite grains, 32.6±13. ppmw, if the two most Ag-rich grains were ignored. Typical depth profiles in pyrite, marcasite and chalcopyrite are given in Appendix A1.

CONCLUSIONS

The ion microprobe analysis of the sulphide grains from the three mill samples from Faro showed that "invisible" Ag is present in the sphalerite, marcasite and chalcopyrite. Pyrite contains "invisible" Ag in significantly lower concentrations. "Invisible" Ag is the silver which is not detectable under the optical or scanning electron microscopes (< 0.1 μm).

Marcasite appears to have the highest Ag content, 61.5±42, ppmw, followed by chalcopyrite at 35.±10. ppmw and sphalerite at 21.2±6.4 ppmw. Pyrite has an average Ag content of 1.6±1.1 ppmw.

Based on a limited number of pyrite grain analyses, it seems that the pyrite from the Zn concentrate has a significantly higher Ag content compared to the pyrite from the final tailings. Pyrite with traces of silver - a known sulphide mineral activator - would dilute the Zn concentrate. The less noble marcasite would tend to oxidize more, which would somewhat counteract the activating action of the silver.

Table 1

"Invisible" Ag in Sphalerite - Faro Ore

Grain #	Ag ppm	Grain #	Ag ppm	Grain #	Ag ppm
1	23.	30	31.	62	8.8
2	9.2	31	18.	63	18.
3	48.	32	24.	64	14.
4	8.	33	8.2	65	8.1
5	30.	38	21.	66	9.2
6	9.1	39	29.	67	10.
7	6.5	42	9.1	68	2.9
8	5.7	43	8.3	69	31.
13	25.	44	2.0	72	11.
14	13.	45	12.	74	19.
15	5.2	46	12.	75	82.
16	14.	47	49.	76	7.4
17	12.	48	20.	78	13
18	3.8	49	26.		
19	25.	51	21.	n = 57	
20	3.6	52	20.		
21	12.	54	9.4	$\hat{x} \pm \lambda$ = 21.2±6.4 ppmw	
22	6.9	55	9.2		
23	66.	56	24.		
25	152.	57	13.		
26	12.	59	7.2		
28	74.	61	38.		

Table 2

"Invisible" Ag in Pyrite, Marcasite and Chalcopyrite - Faro Ore

Pyrite	
Grain #	Ag ppm
10	9.3
12	5.7
50	4.9
53	1.2
60	4.6
3'	.01 < MDL
7'	.18 < MDL
8'	.06 < MDL
10'	.08 < MDL
11'	.40
12'	.04 < MDL
13'	.06 < MDL
16'	.45 < MDL
17'	.06 < MDL
18'	.07 < MDL
19'	.1 < MDL
20'	.06 < MDL
34	1.2
36	13.*
41	1.2
73	1.4
n = 20	
$\hat{x} \pm \lambda$ = 1.6±1.1 ppmw	

Marcasite	
Grain #	Ag ppm
24	295.
27	39.
58	116.
79	47.
1'	1.8
2'	33.
4'	24.
5'	8.
6'	53.
9'	53.
14'	14.
15'	54.
n = 12	
$\hat{x} \pm \lambda$ = 61.5±42. ppmw	
n = 10	
$\hat{x} \pm \lambda$ = 32.6±13. ppmw	

Chalcopyrite	
Grain #	Ag ppm
29	47.
35	32.
77	26.
n = 3	
$\hat{x} \pm \lambda$ = 35.±10. ppmw	

* Minor marcasite

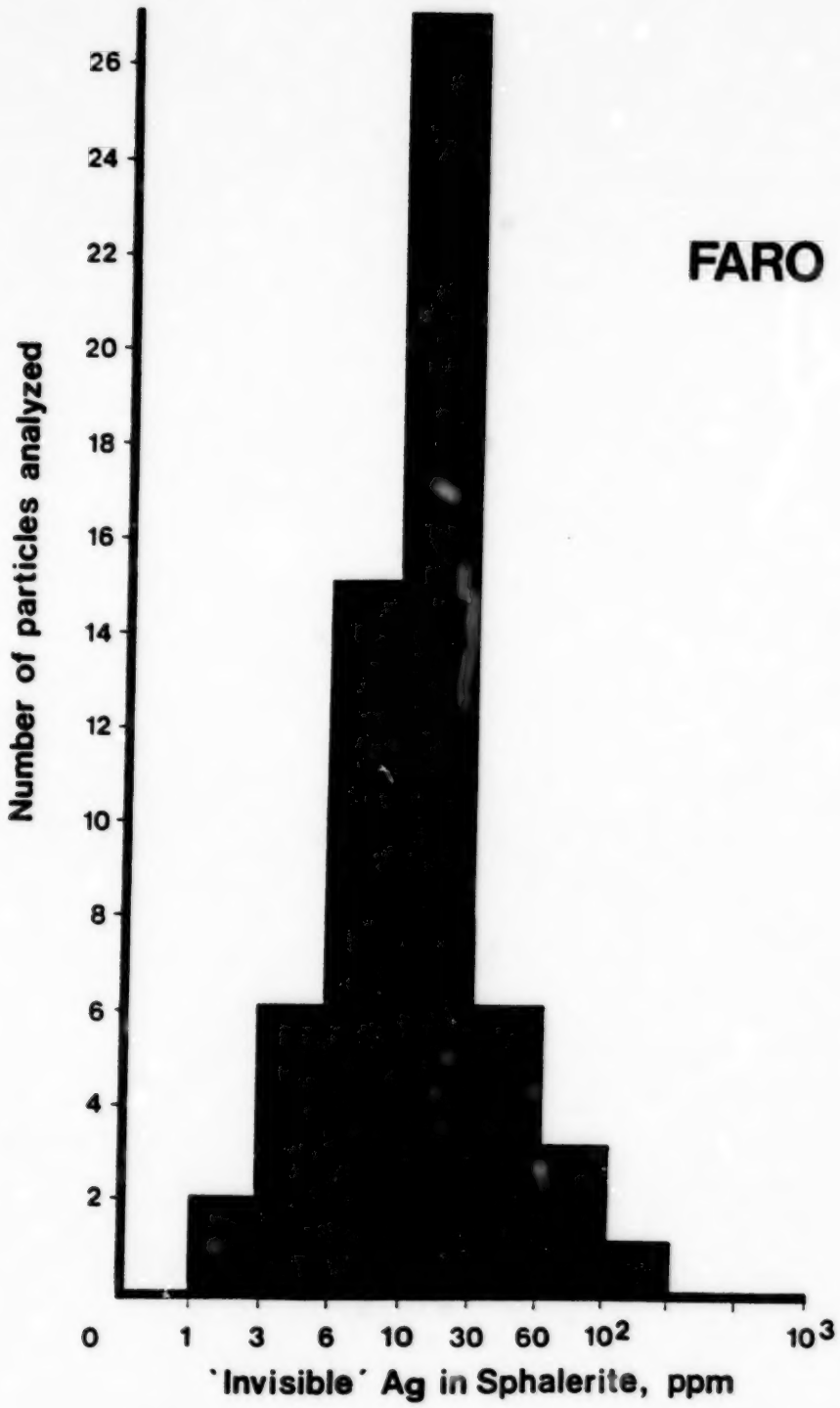


Figure 1 - Histogram of "invisible" Ag concentration in 57 sphalerite grains from Faro

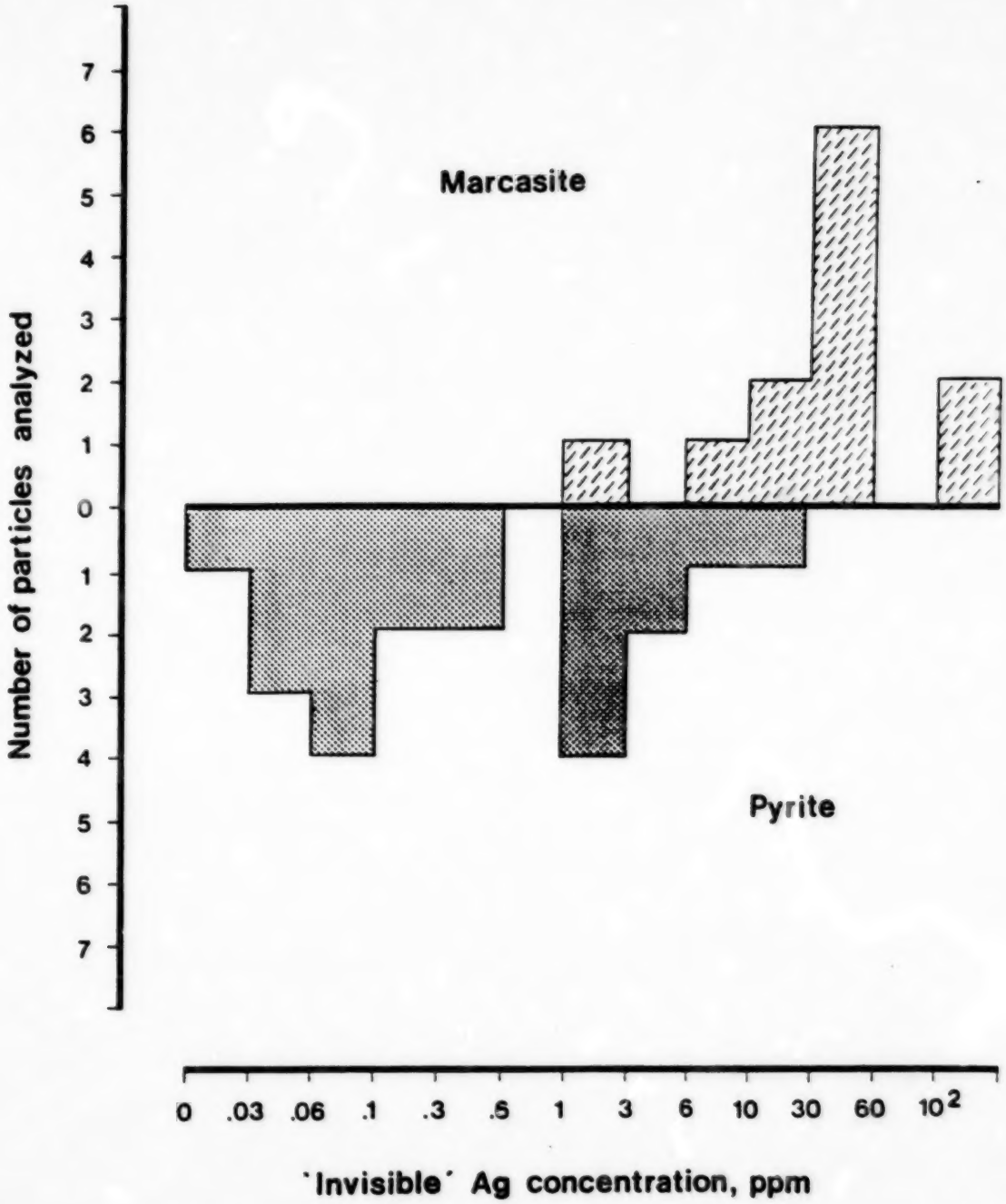
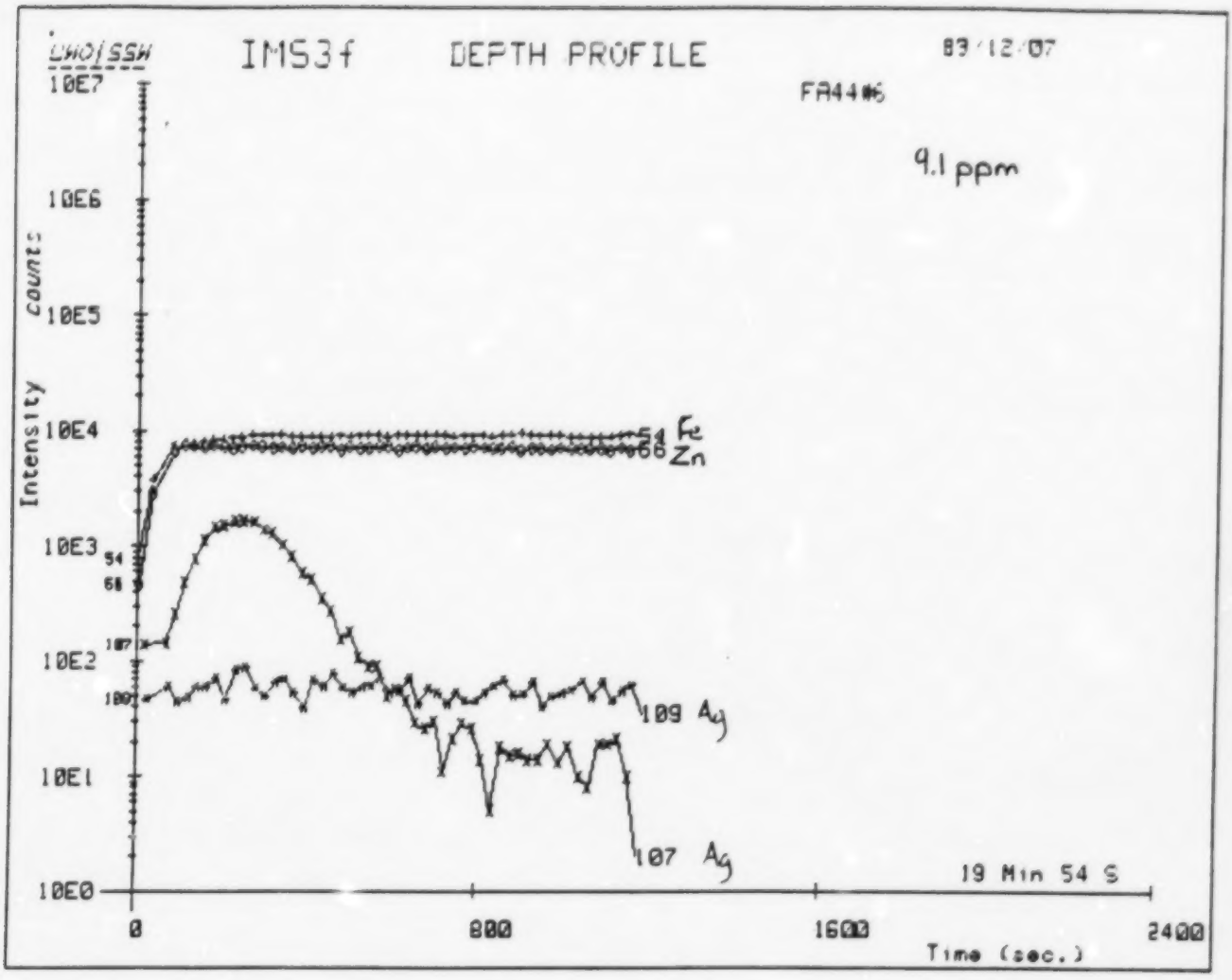


Figure 2 - Histograms of "invisible" Ag concentration in marcasite and pyrite grains from Faro

Appendix A1

Selected SIMS Data

Sphalerite



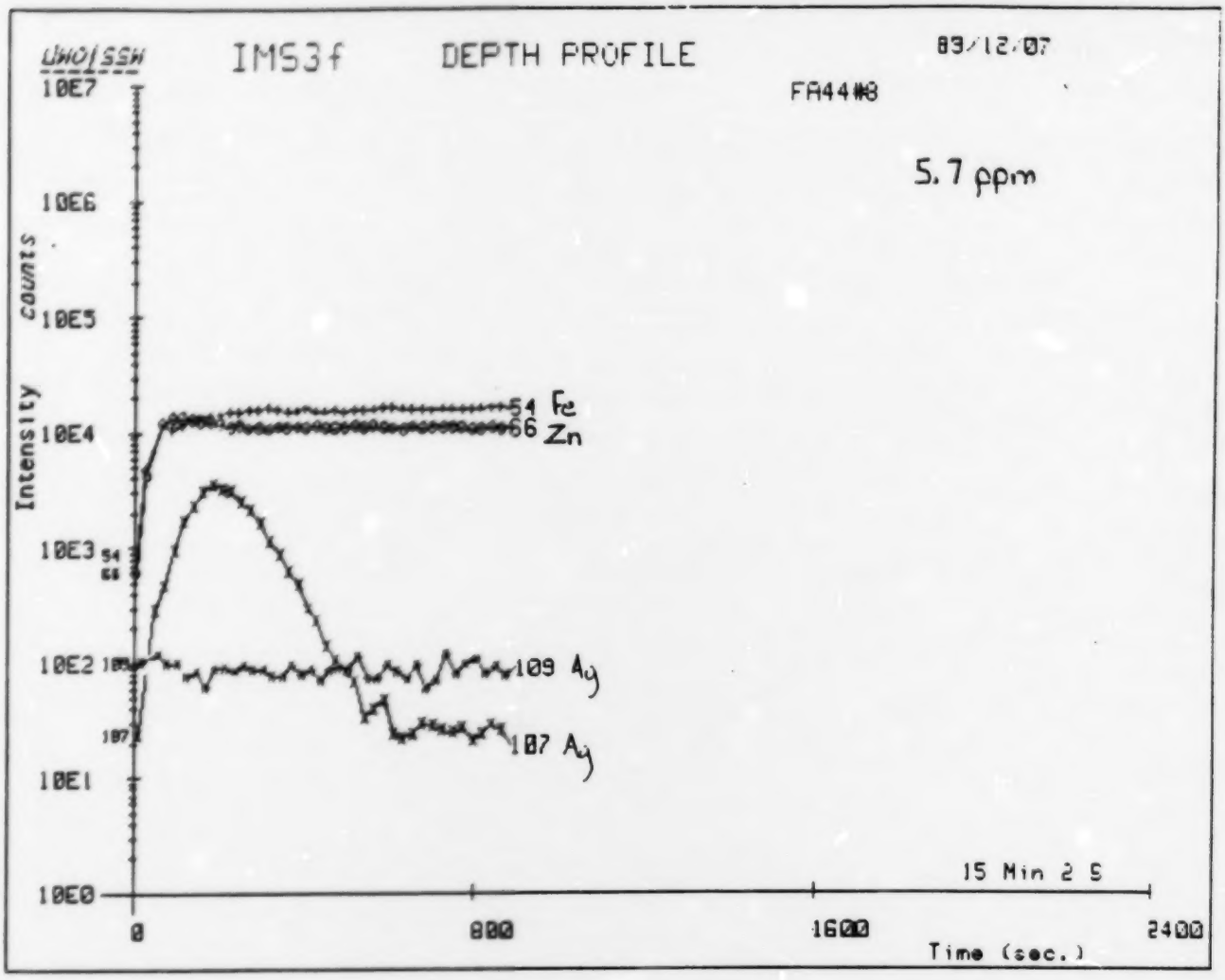
SAMPLE:FA44#6 OSp
DATE:89/12/07
PRIMARY IONS : OXYGEN -
SECONDARY IONS : +
DEAD TIME: 500.00E-10 sec.

PRIMARY CURRENT : 507 NANO AMP
HIGH VOLTAGE : 12.6 KILOVOLTS
RASTERING : 250 MICRONS
TRANSFER OPTICS : 150 MICRONS
FIELD APERTURE : 1 2 3
CONTRAST APERTURE : 4 3 2 1

Manual

MASS NUMBER : 54.00 COUNT TIME : .10 OFFSET VOLTAGE : 0.00
M.F.P.: 27023 7

TIME(SEC)	COUNT	TIME(SEC)	COUNT	TIME(SEC)	COUNT	TIME(SEC)	COUNT
3	768	35	3807	85	7526	107	7469
130	7747	153	8085	175	8479	198	8472
221	8599	243	8743	266	9012	289	8943
311	8989	334	9043	357	8694	380	8906
402	8830	425	8699	448	8902	470	8927
493	8832	516	8953	538	9153	561	9094
584	8798	606	9139	629	9034	652	9097
674	9008	697	8983	720	9074	742	8886



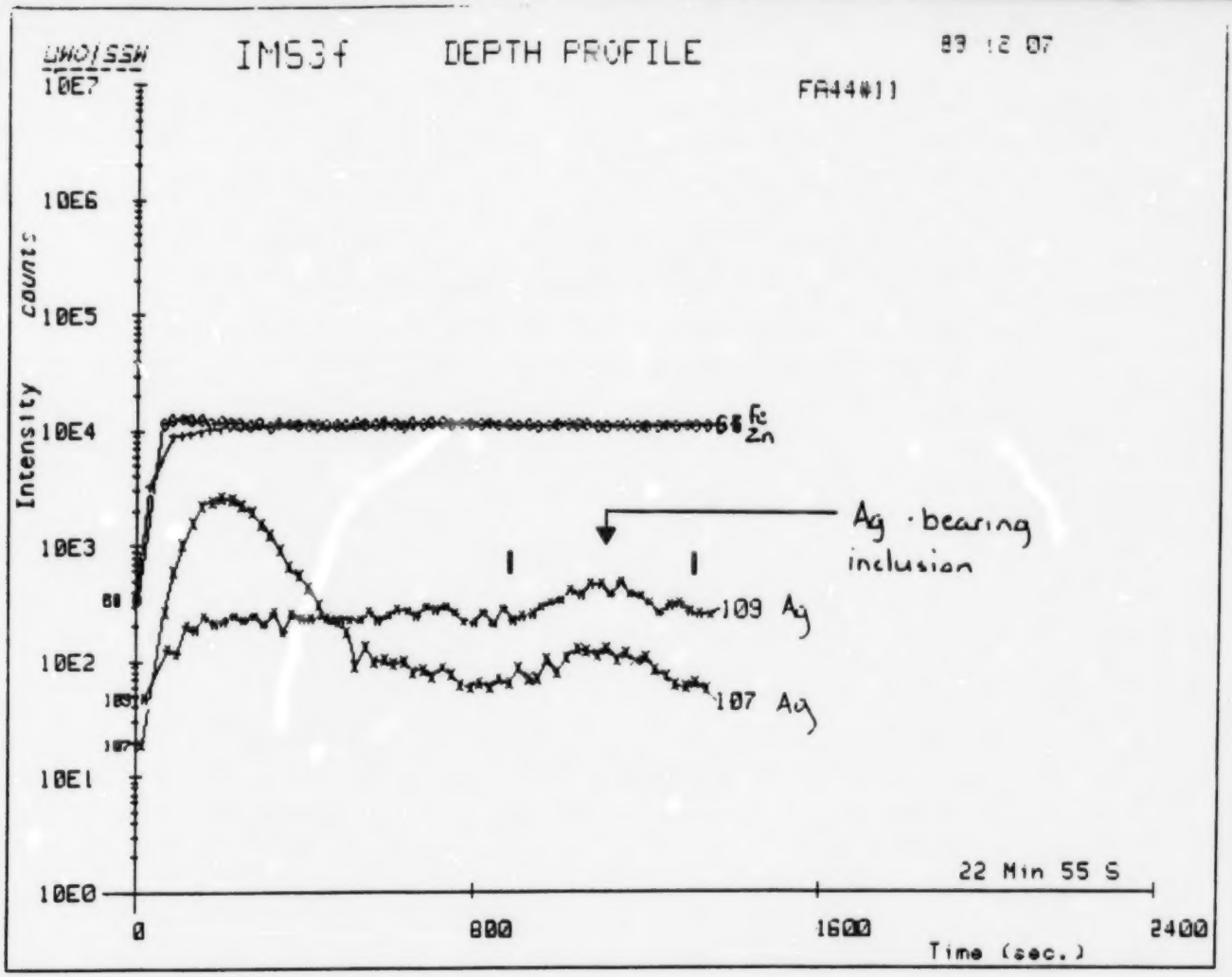
SAMPLE:FA44#8 O 5%
DATE:89/12/07
PRIMARY IONS : OXYGEN -
SECONDARY IONS : +
DEAD TIME: 500.00E-10 sec.

PRIMARY CURRENT : 536 NANO AMP
HIGH VOLTAGE : 12.7 KILOVOLTS
RASTERING : 250 MICRONS
TRANSFER OPTICS : 150 MICRONS
FIELD APERTURE : 1 2 3
CONTRAST APERTURE : 4 3 2 1

Manual

MASS NUMBER : 54.00 COUNT TIME : .10 OFFSET VOLTAGE : 0.00
M.F.P.: 27023 7

TIME(SEC)	COUNT	TIME(SEC)	COUNT	TIME(SEC)	COUNT	TIME(SEC)	COUNT
4	884	26	4906	66	11482	88	10816
111	11819	134	12961	156	13615	179	13974
202	14358	225	15011	247	15003	270	15828
293	15572	315	16271	338	15674	361	15168
383	15425	406	16123	429	15370	451	15345
474	15864	497	15143	519	15563	542	15957
565	16068	587	16237	610	16365	633	16011
655	15956	678	15738	701	15538	723	16034
746	15972	769	15818	791	15741	814	15999



SAMPLE:FA44#11 Osp
DATE:89/12/07
PRIMARY IONS : OXYGEN -
SECONDARY IONS : +
DEAD TIME: 500.00E-10 sec.

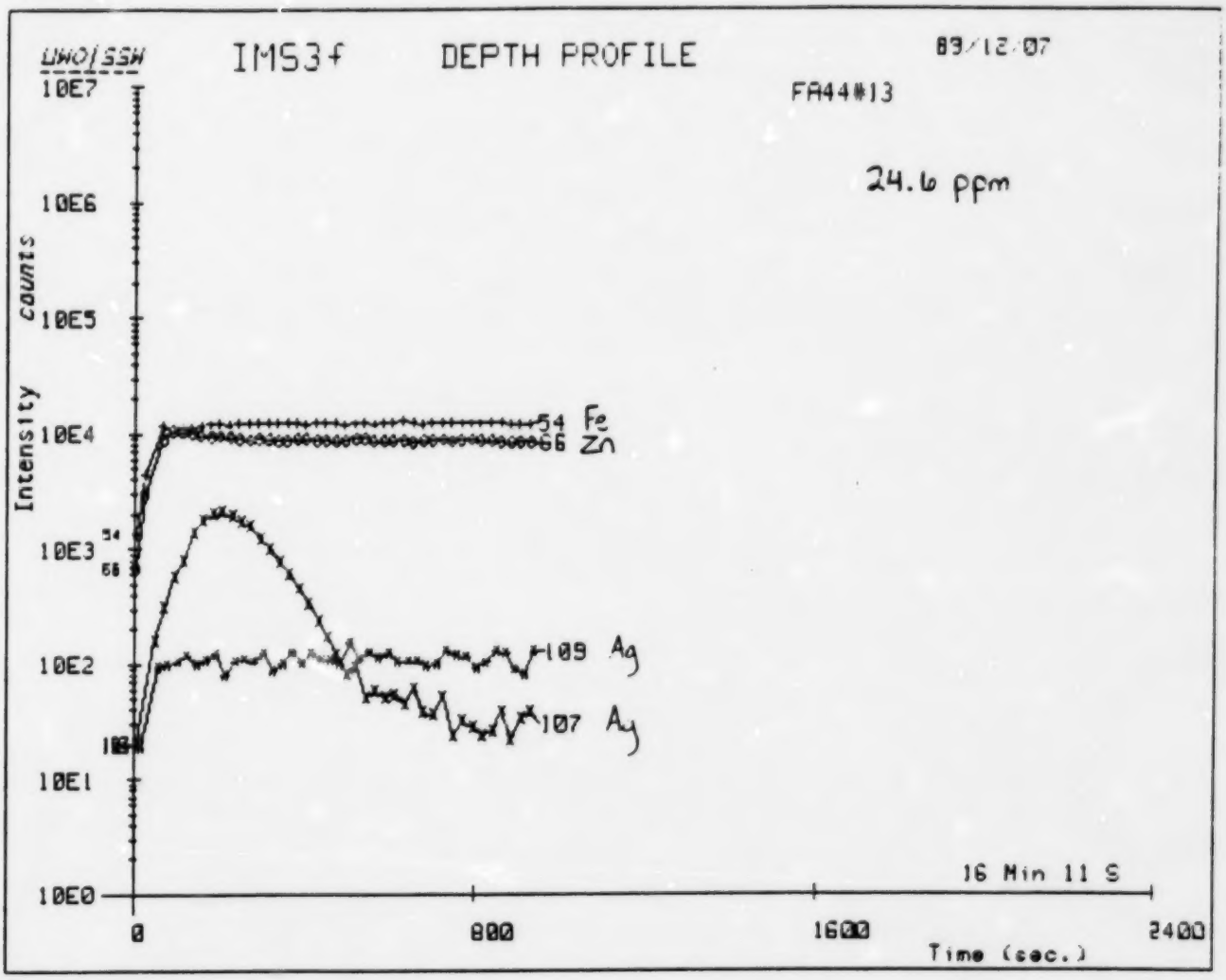
Inclusion

PRIMARY CURRENT : 454 NANO AMP
HIGH VOLTAGE : 12.7 KILOVOLTS
RASTERING : 250 MICRONS
TRANSFER OPTICS : 150 MICRONS
FIELD APERTURE : 1 2 3
CONTRAST APERTURE : 4 3 2 1

Manual

MASS NUMBER : 54.00 COUNT TIME : .10 OFFSET VOLTAGE : 0.00
M.F.P.: 27030 5

TIME(SEC)	COUNT	TIME(SEC)	COUNT	TIME(SEC)	COUNT	TIME(SEC)	COUNT
3	338	31	3231	85	8913	107	9109
130	9328	153	9960	176	10442	198	10126
221	10707	244	10466	266	10656	289	10923
312	10816	334	11062	357	10648	380	10739
402	11079	425	10417	448	10529	470	11121
493	10343	516	10448	538	10937	561	10875
584	10836	606	10620	629	10687	652	10812
674	11172	697	10924	720	11060	742	10988
765	11160	788	10767	811	11135	833	11032
856	10612	879	10915	901	10842	924	10759



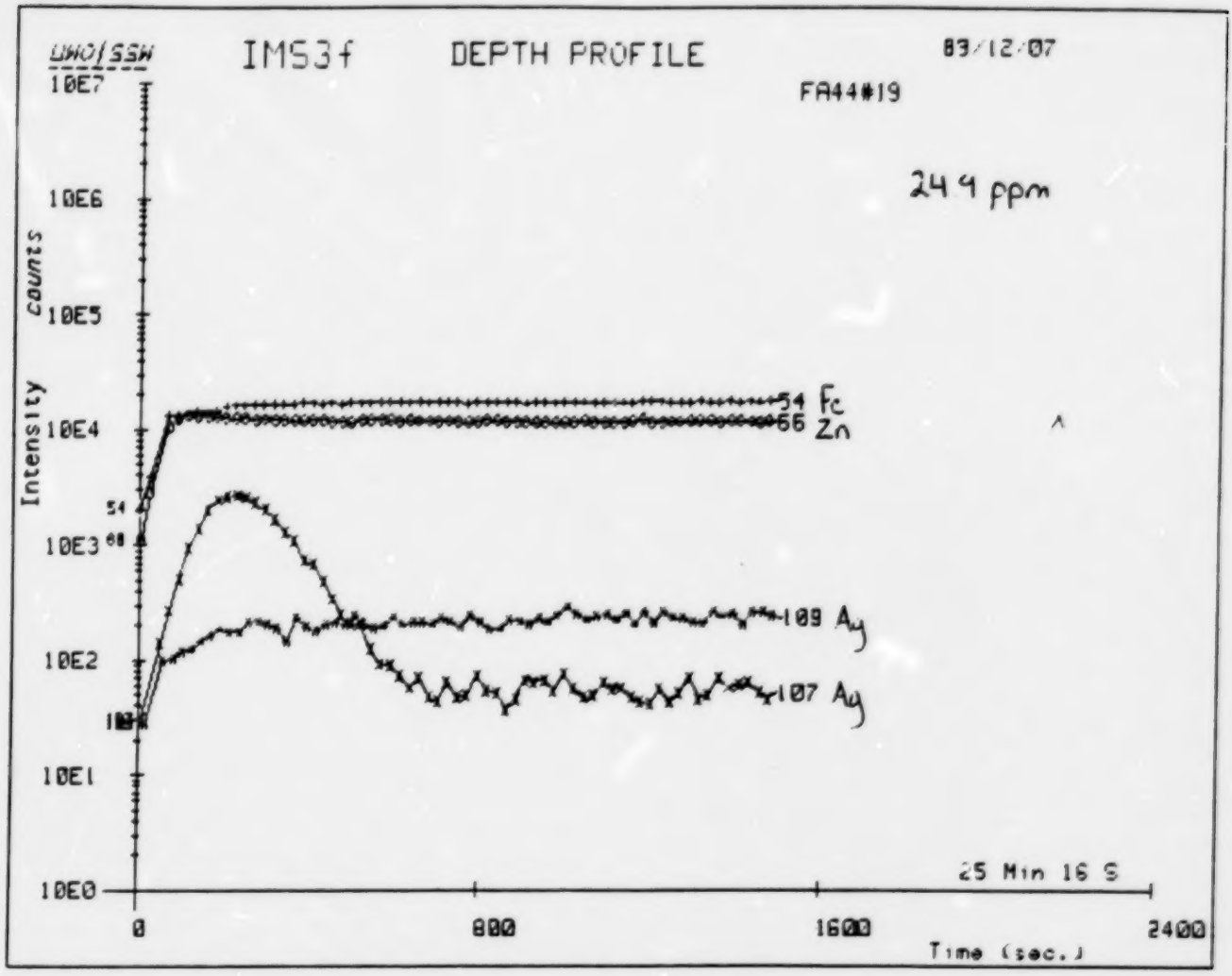
SAMPLE:FA44#13 O SP
DATE:89/12/07
PRIMARY IONS : OXYGEN -
SECONDARY IONS : +
DEAD TIME: 500.00E-10 sec.

PRIMARY CURRENT : 422 NANO AMP
HIGH VOLTAGE : 12.7 KILOVOLTS
RASTERING : 250 MICRONS
TRANSFER OPTICS : 150 MICRONS
FIELD APERTURE : 1 2 3
CONTRAST APERTURE : 4 3 2 1

Manual

MASS NUMBER : 54.00 COUNT TIME : .10 OFFSET VOLTAGE : 0.00
M.F.P.: 27030 5

TIME(SEC)	COUNT	TIME(SEC)	COUNT	TIME(SEC)	COUNT	TIME(SEC)	COUNT
4	1360	24	4447	66	11774	89	11002
111	11135	134	11289	157	11809	179	12041
202	12229	225	11942	247	12165	270	12357
293	12290	316	12248	338	12214	361	12264
384	12239	406	11877	429	12327	452	12210



SP

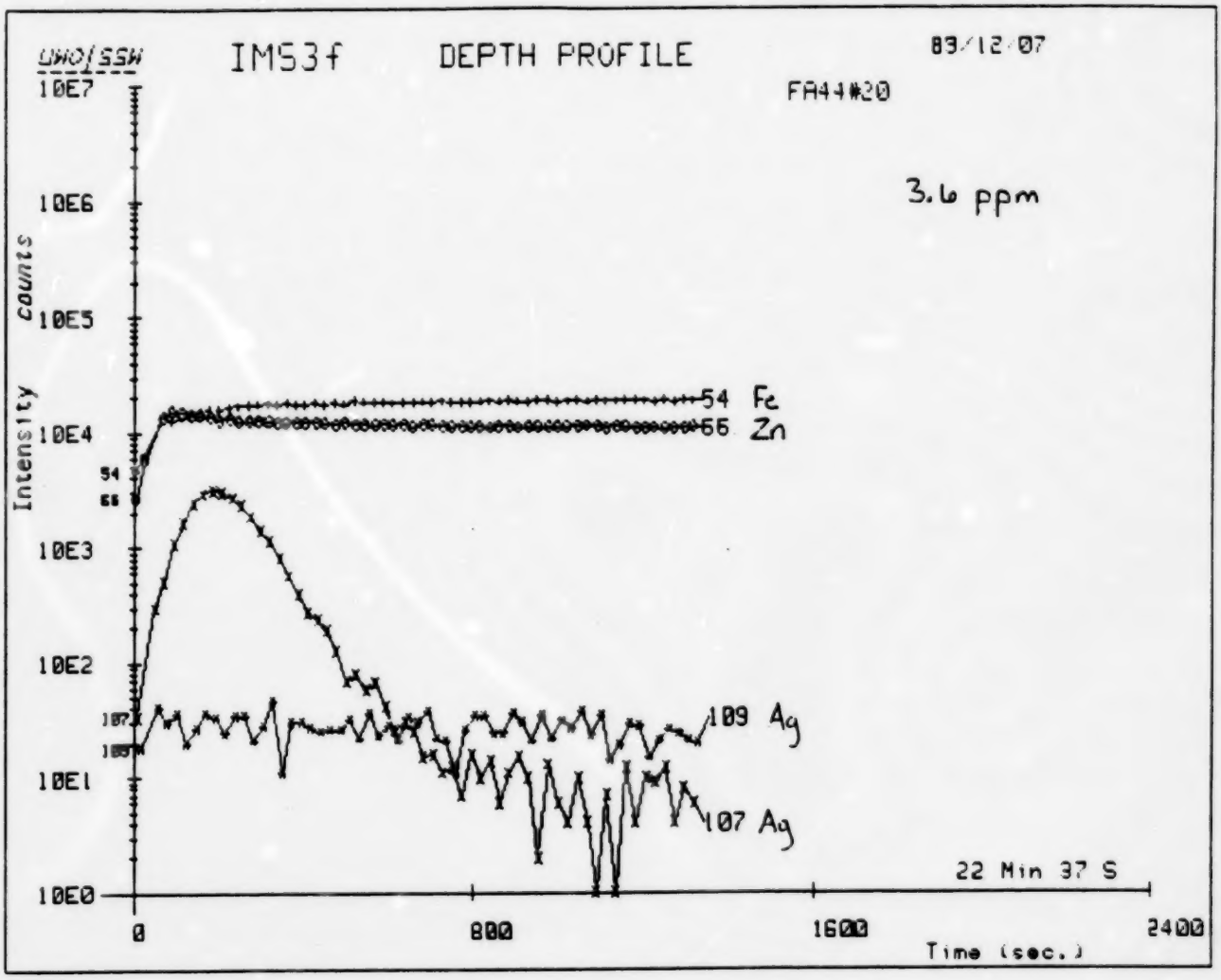
SAMPLE:FA44#19
DATE:89/12/07
PRIMARY IONS : OXYGEN -
SECONDARY IONS : +
DEAD TIME: 500.00E-10 sec.

PRIMARY CURRENT : 498 NANO AMP
HIGH VOLTAGE : 12.6 KILOVOLTS
RASTERING : 250 MICRONS
TRANSFER OPTICS : 150 MICRONS
FIELD APERTURE : 1 2 3
CONTRAST APERTURE : 4 3 2 1

Manual

MASS NUMBER : 54.00 COUNT TIME : .10 OFFSET VOLTAGE : 0.00
M.F.P.: 27030 5

TIME(SEC)	COUNT	TIME(SEC)	COUNT	TIME(SEC)	COUNT	TIME(SEC)	COUNT
3	2090	24	3913	66	13350	89	13450
112	13634	134	14292	157	14585	180	14784
203	15557	225	16111	248	16154	271	16649
293	16419	316	16521	339	16586	361	16309
384	16956	407	16914	429	16265	452	16905



SP

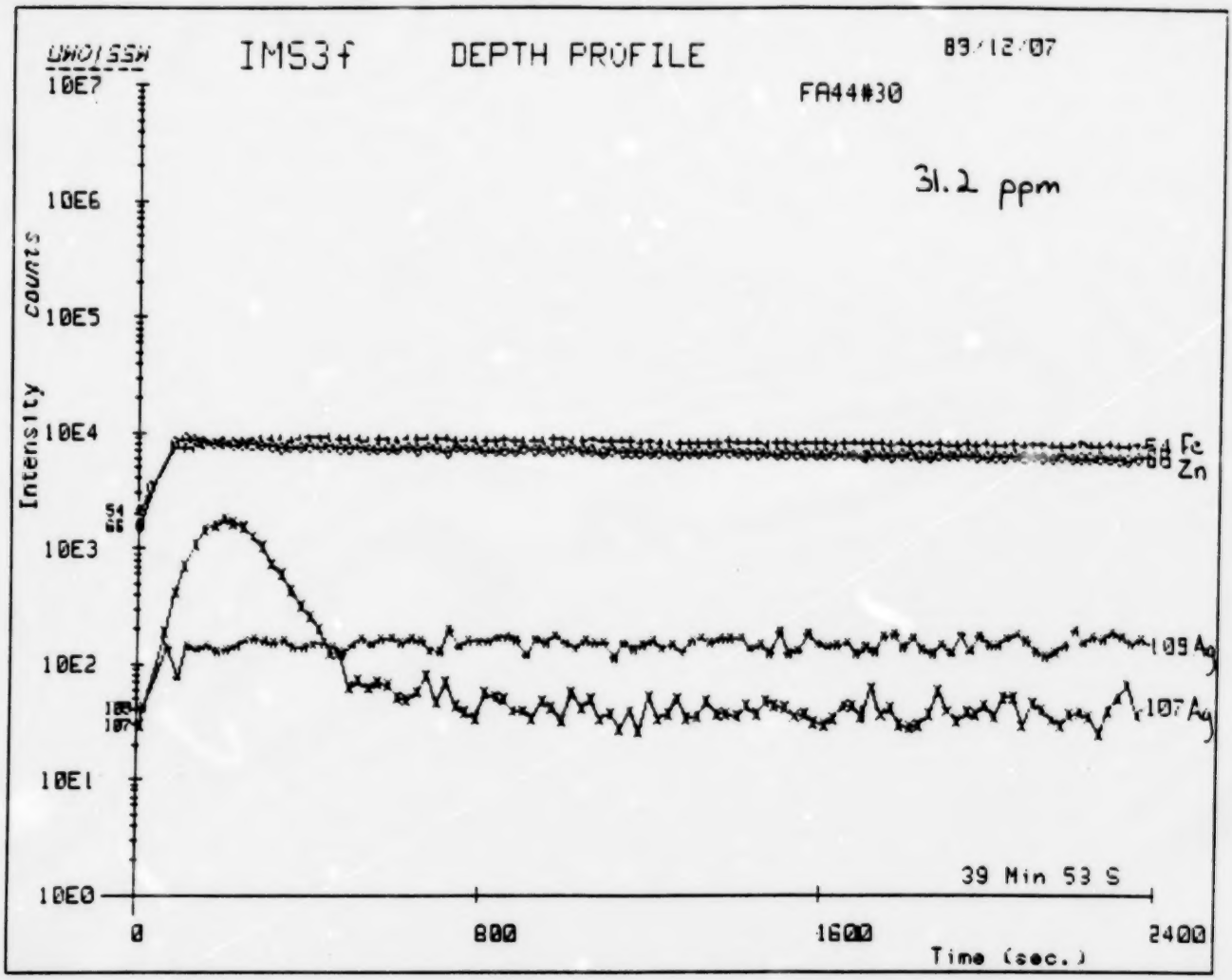
SAMPLE:FA44#20
DATE:89/12/07
PRIMARY IONS : OXYGEN -
SECONDARY IONS : +
DEAD TIME: 500.00E-10 sec.

PRIMARY CURRENT : 500 NANO AMP
HIGH VOLTAGE : 12.7 KILOVOLTS
RASTERING : 250 MICRONS
TRANSFER OPTICS : 150 MICRONS
FIELD APERTURE : 1 2 3
CONTRAST APERTURE : 4 3 2 1

Manual

MASS NUMBER : 54.00 COUNT TIME : .10 OFFSET VOLTAGE : 0.00
M.F.P.: 27030 5

TIME(SEC)	COUNT	TIME(SEC)	COUNT	TIME(SEC)	COUNT	TIME(SEC)	COUNT
3	4575	24	6392	66	13304	89	12904
112	13529	134	14782	157	15409	180	15925
202	15963	225	16596	248	16817	270	17053
293	17449	316	17573	338	17367	361	18047



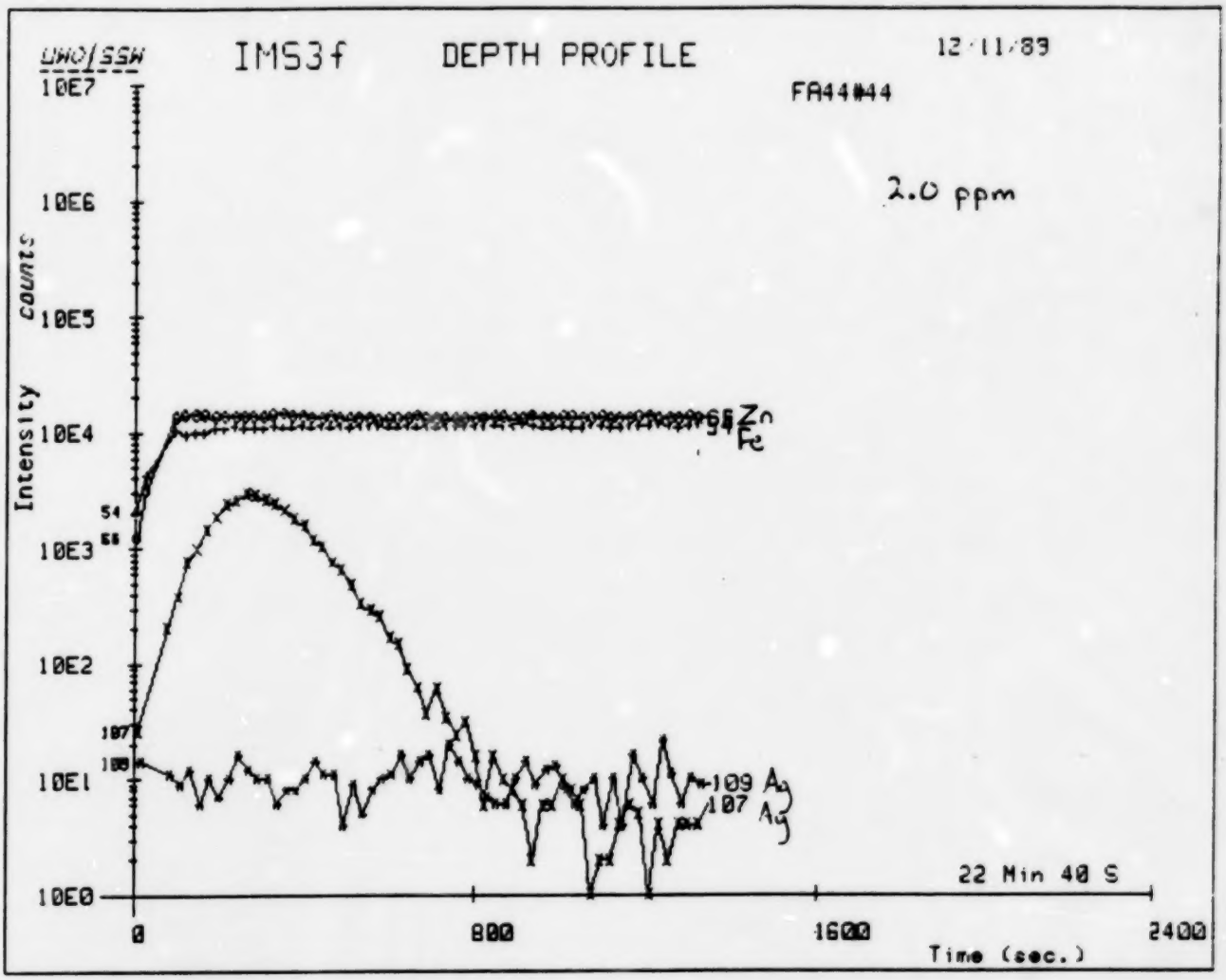
SAMPLE:FA44#30
DATE:89/12/07
PRIMARY IONS : OXYGEN -
SECONDARY IONS : +
DEAD TIME: 500.00E-10 sec.

PRIMARY CURRENT : 462 NANO AMP
HIGH VOLTAGE : 12.6 KILOVOLTS
RASTERING : 250 MICRONS
TRANSFER OPTICS : 150 MICRONS
FIELD APERTURE : 1 2 3
CONTRAST APERTURE : 4 3 2 1

Manual

MASS NUMBER : 54.00 COUNT TIME : .10 OFFSET VOLTAGE : 0.00
M.F.P.: 27030 5

TIME(SEC)	COUNT	TIME(SEC)	COUNT	TIME(SEC)	COUNT	TIME(SEC)	COUNT
3	2147	24	2785	83	7340	106	7250
129	7433	151	8133	174	8239	197	8425
220	8473	242	8449	265	8580	288	8957
310	8839	333	8641	356	8458	378	8740
401	8944	424	8956	446	9011	469	8725



SAMPLE:FA44#44
DATE:12/11/89
PRIMARY IONS : OX -
SECONDARY IONS : +
DEAD TIME: 500.00E-10 sec.

Och

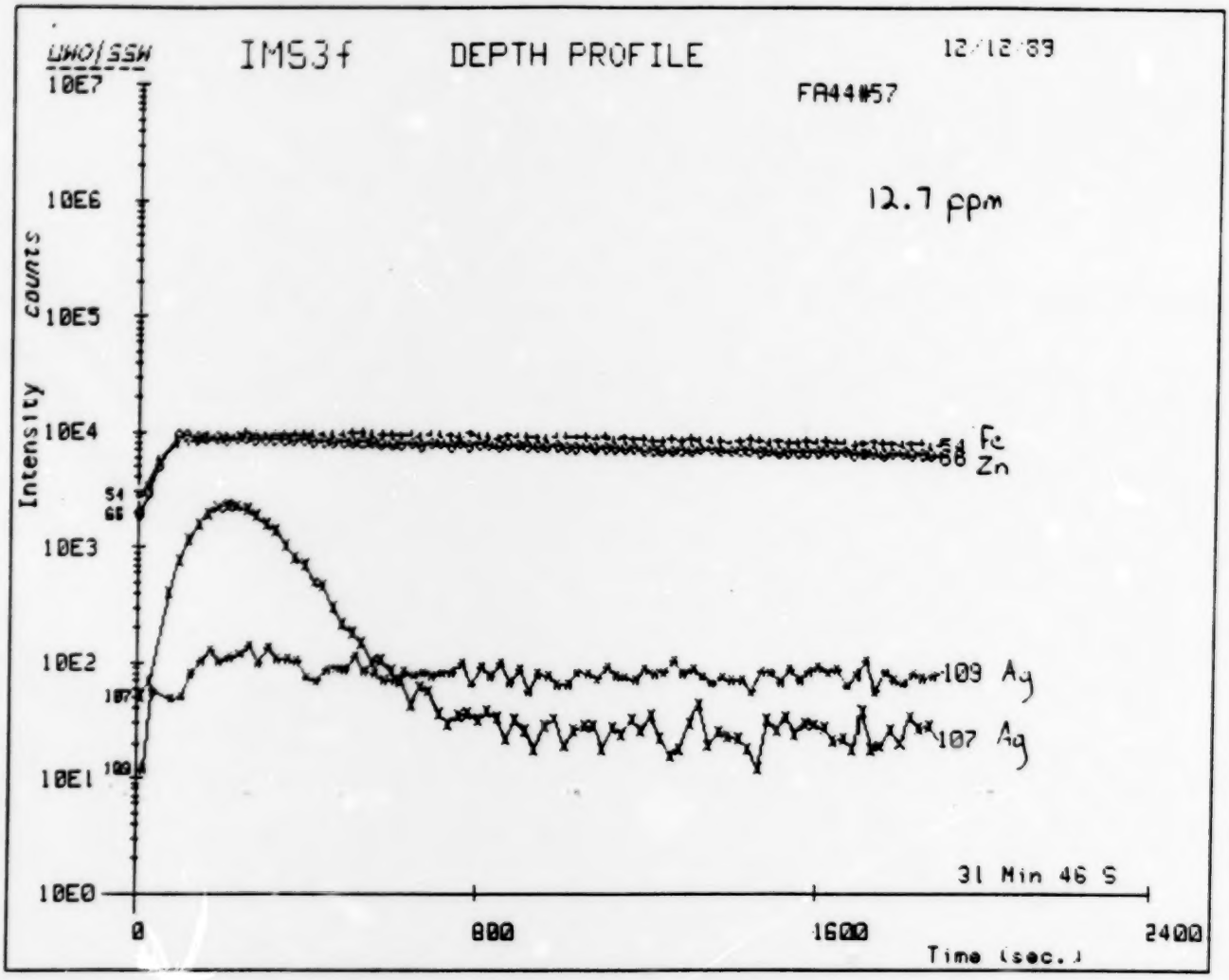
PRIMARY CURRENT : 409 NANO AMP
HIGH VOLTAGE : 12.6 KILOVOLTS
RASTERING : 250 MICRONS
TRANSFER OPTICS : 150 MICRONS
FIELD APERTURE : 1 2 3
CONTRAST APERTURE : 4 3 2 1

125 V off

Manual

MASS NUMBER : 54.00 COUNT TIME : .10 OFFSET VOLTAGE : 0.00
M.F.P.: 27025 1

TIME(SEC)	COUNT	TIME(SEC)	COUNT	TIME(SEC)	COUNT	TIME(SEC)	COUNT
3	2105	24	4293	93	10267	116	9603
139	9916	161	9939	184	10650	207	10557
229	11190	252	10727	275	10733	297	10658
320	11129	343	10935	365	10953	388	11011
411	10927	433	11064	456	10918	479	11149



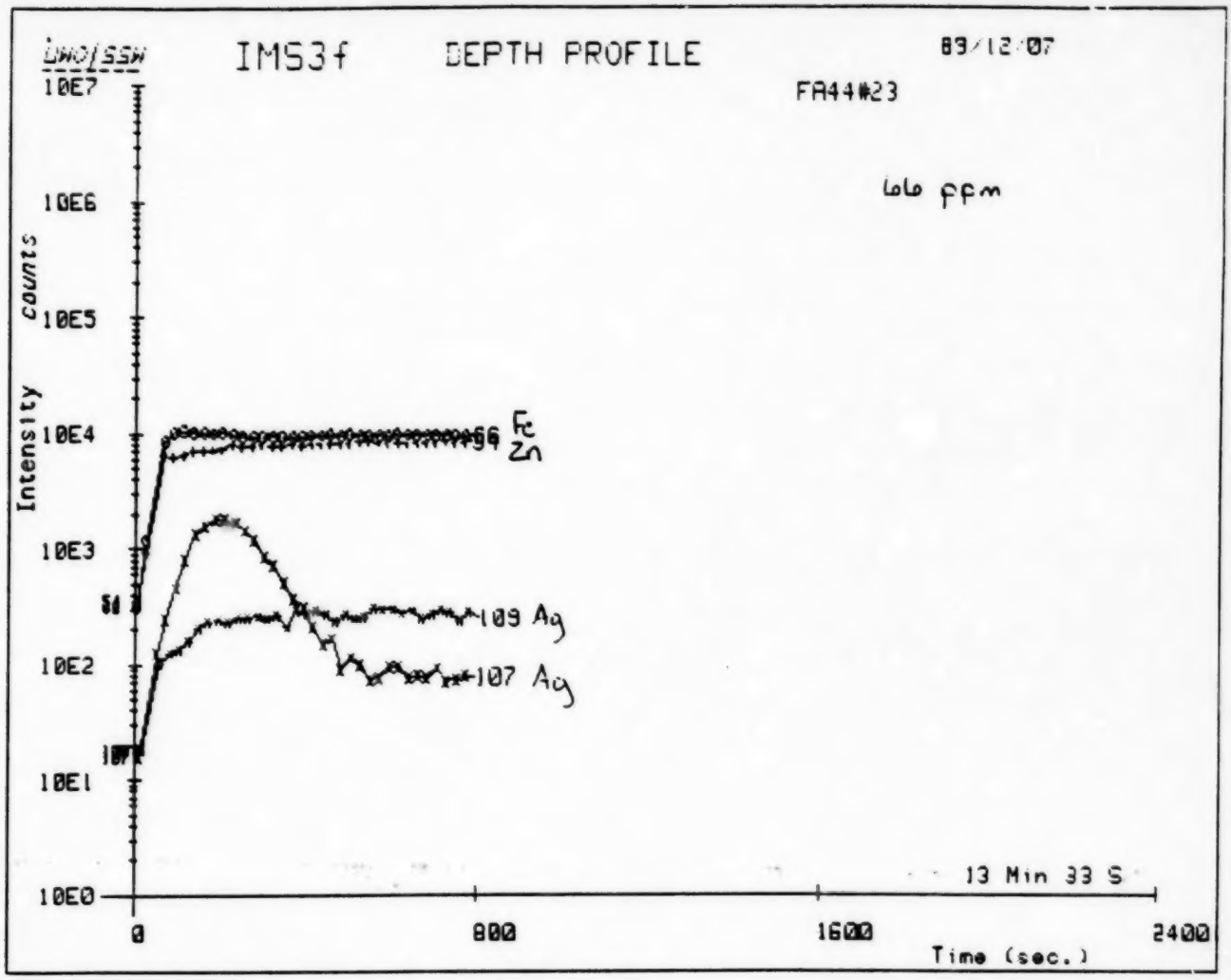
SAMPLE:FA44#57
DATE:12/12/89
PRIMARY IONS : 0X -
SECONDARY IONS : +
DEAD TIME: 500.00E-10 sec.

PRIMARY CURRENT : 406 NANO AMP
HIGH VOLTAGE : 12.6 KILOVOLTS
RASTERING : 250 MICRONS
TRANSFER OPTICS : 150 MICRONS
FIELD APERTURE : 1 2 3
CONTRAST APERTURE : 4 3 2 1

Manual

MASS NUMBER : 54.00 COUNT TIME : .10 OFFSET VOLTAGE : 0.00
M.F.P.: 27023 4

TIME(SEC)	COUNT	TIME(SEC)	COUNT	TIME(SEC)	COUNT	TIME(SEC)	COUNT
3	2838	24	3650	47	5763	93	7947
116	8358	139	8468	161	8938	184	9192
207	8998	230	9222	252	9781	275	9523
298	9230	320	9616	343	9672	366	9579
388	9464	411	9670	434	9347	456	9564
479	9497	502	9945	524	9826	547	9598



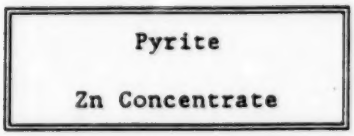
SAMPLE:FA44#23
DATE:89/12/07
PRIMARY IONS : OXYGEN -
SECONDARY IONS : +
DEAD TIME: 500.00E-10 sec.

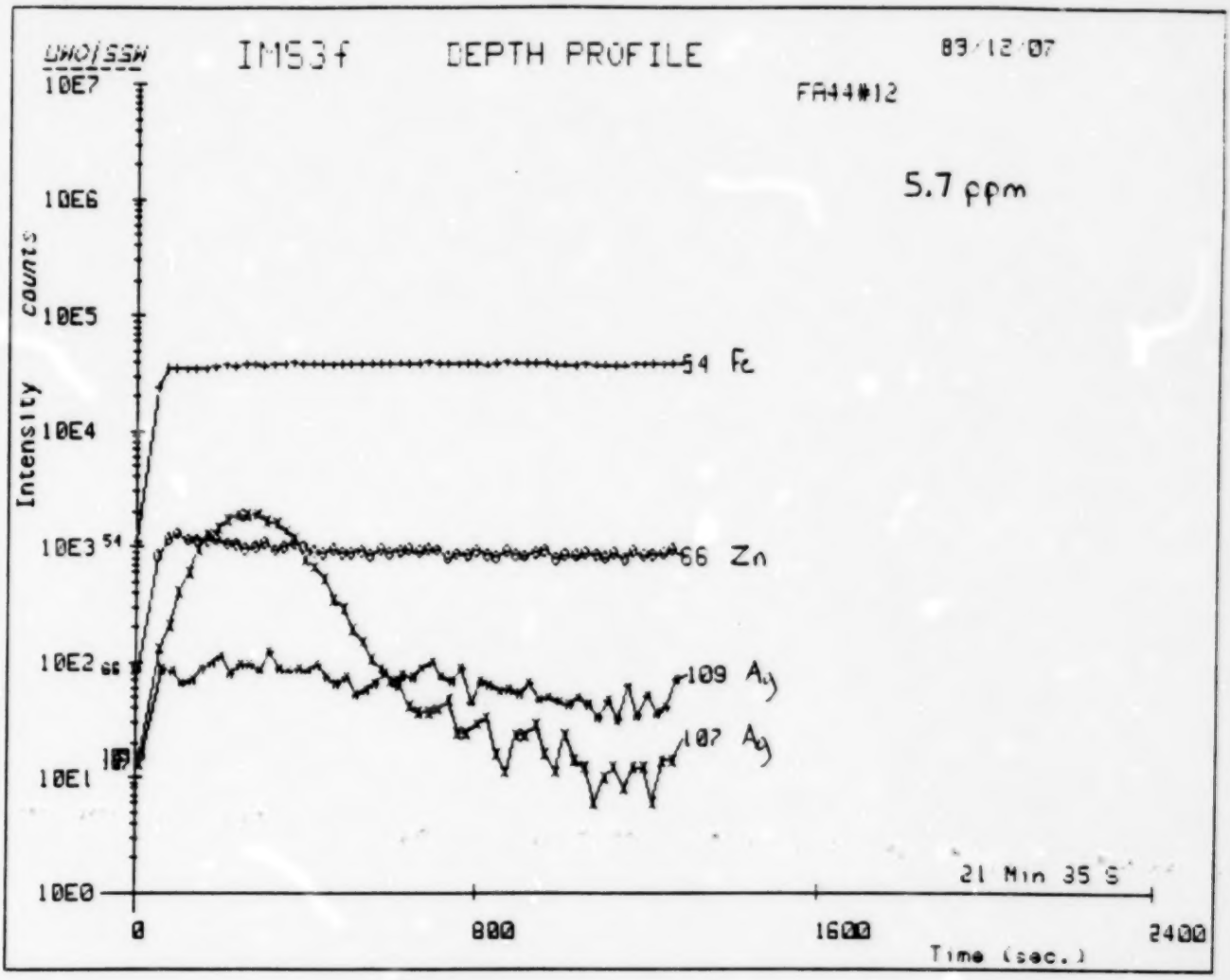
PRIMARY CURRENT : 493 NANO AMP
HIGH VOLTAGE : 12.6 KILOVOLTS
RASTERING : 250 MICRONS
TRANSFER OPTICS : 150 MICRONS
FIELD APERTURE : 1 2 3
CONTRAST APERTURE : 4 3 2 1

Manual

MASS NUMBER : 54.00 COUNT TIME : .10 OFFSET VOLTAGE : 0.00
M.F.P.: 27030 5

TIME(SEC)	COUNT	TIME(SEC)	COUNT	TIME(SEC)	COUNT	TIME(SEC)	COUNT
4	358	24	914	66	6539	89	6289
112	6523	134	7101	157	7067	180	7192
202	7242	225	7943	248	7781	271	7598
293	7893	316	7765	339	7700	361	7872
384	7642	407	8062	429	8028	452	7902
475	8104	497	8008	520	8203	543	8278
565	8154	588	7925	611	8068	633	7984
656	8008	679	8046	701	7852	724	8268
[illegible]	7933	769	8102	792	8252	0	0


Pyrite
Zn Concentrate



OPy

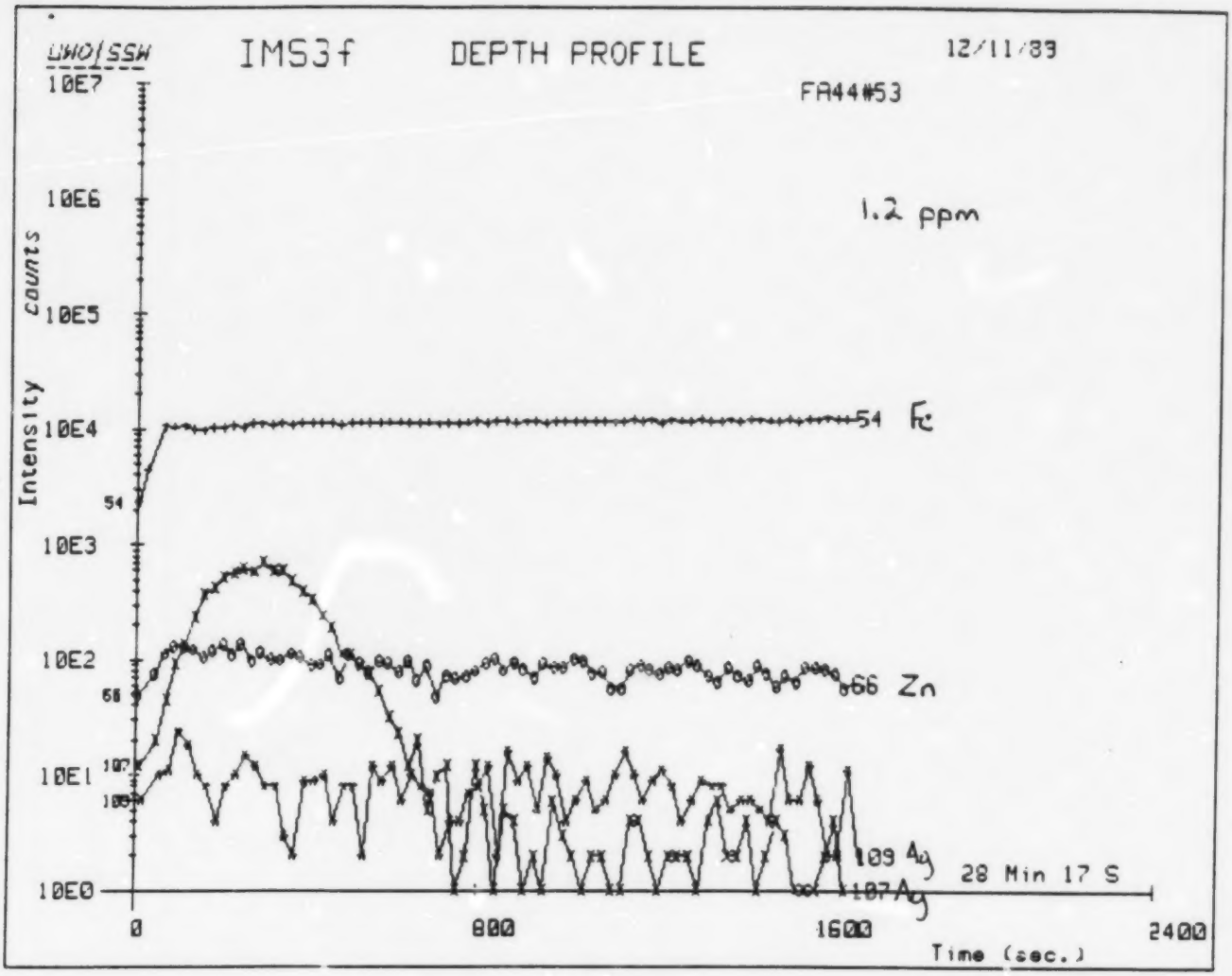
SAMPLE:FA44#12
DATE:89/12/07
PRIMARY IONS : OXYGEN -
SECONDARY IONS : +
DEAD TIME: 500.00E-10 sec.

PRIMARY CURRENT : 465 NANO AMP
HIGH VOLTAGE : 12.6 KILOVOLTS
RASTERING : 250 MICRONS
TRANSFER OPTICS : 150 MICRONS
FIELD APERTURE : 1 2 3
CONTRAST APERTURE : 4 3 2 1

Manual

MASS NUMBER : 54.00 COUNT TIME : .10 OFFSET VOLTAGE : 0.00
M.F.P.: 27030 5

TIME(SEC)	COUNT	TIME(SEC)	COUNT	TIME(SEC)	COUNT	TIME(SEC)	COUNT
3	1120	50	24197	73	34956	95	35814
118	34623	141	35628	163	35536	186	36441
209	37590	231	36570	254	38085	277	38068
299	36881	322	37624	345	38327	367	39326
390	38123	413	38710	435	38713	458	37759
481	38794	503	38642	526	38438	549	37805
572	37874	594	38239	617	39091	640	38089



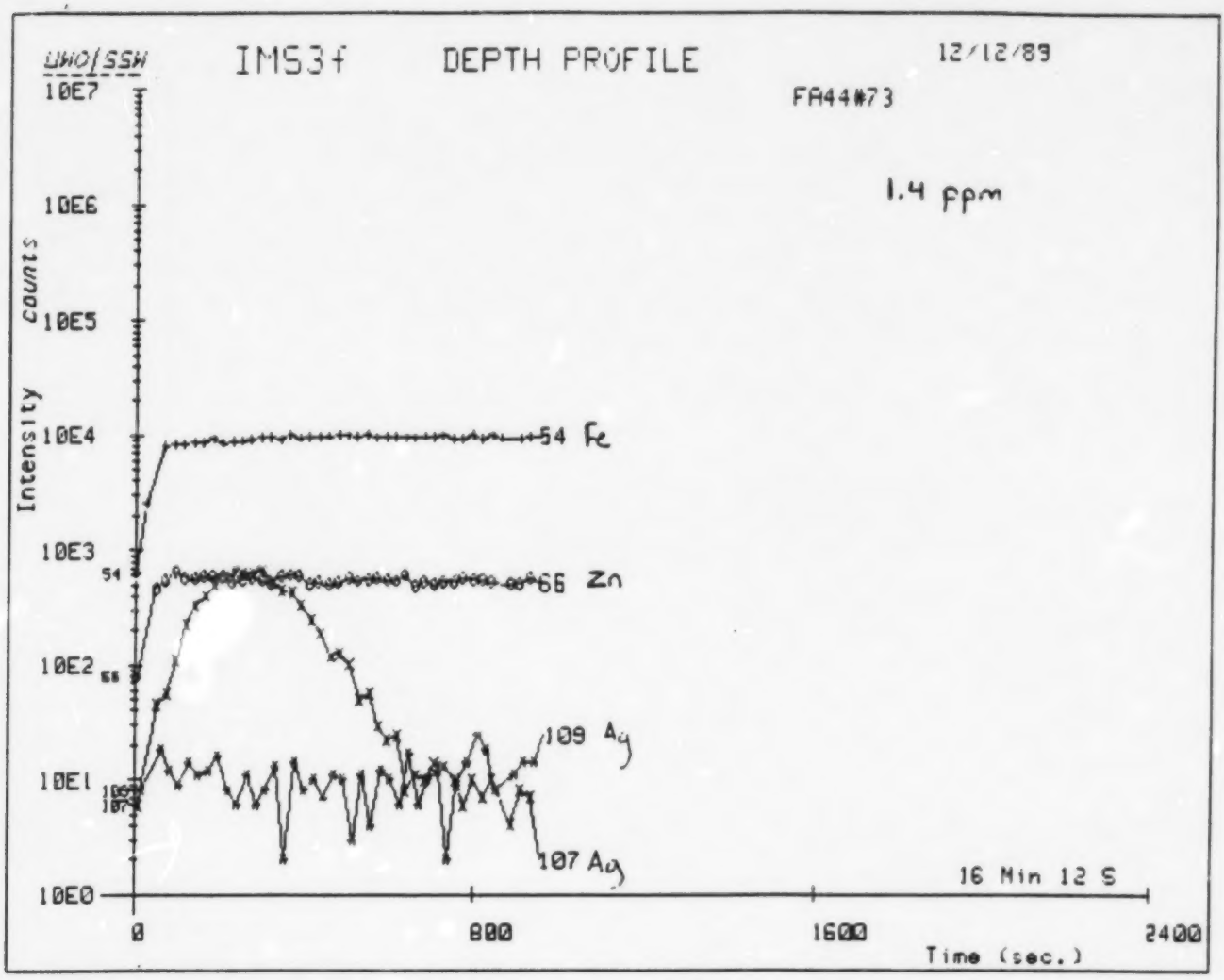
SAMPLE:FA44#53
DATE:12/11/89
PRIMARY IONS : OX -
SECONDARY IONS : +
DEAD TIME: 500.00E-10 sec.

PRIMARY CURRENT : 417 NANO AMP
HIGH VOLTAGE : 12.7 KILOVOLTS
RASTERING : 250 MICRONS
TRANSFER OPTICS : 150 MICRONS
FIELD APERTURE : 1 2 3
CONTRAST APERTURE : 4 3 2 1

Manual

MASS NUMBER : 54.00 COUNT TIME : .:0 OFFSET VOLTAGE : 0.00
M.F.P.: 27025 1

TIME(SEC)	COUNT	TIME(SEC)	COUNT	TIME(SEC)	COUNT	TIME(SEC)	COUNT
4	2328	25	4526	67	10581	90	10473
113	10579	135	9771	158	9755	181	10204
203	10285	226	10727	249	10438	271	11147
294	11040	317	10866	339	11218	362	10716
385	11093	407	11126	430	11133	453	11113
475	10907	498	11212	521	11396	543	11206
566	11293	589	11404	612	11400	634	11296
657	11246	680	11420	702	11046	725	11198



SAMPLE:FA44#73
DATE:12/12/89
PRIMARY IONS : OX -
SECONDARY IONS : +
DEAD TIME: 500.00E-10 sec.

PRIMARY CURRENT : 448 NANO AMP
HIGH VOLTAGE : 12.6 KILOVOLTS
RASTERING : 250 MICRONS
TRANSFER OPTICS : 150 MICRONS
FIELD APERTURE : 1 2 3
CONTRAST APERTURE : 4 3 2 1

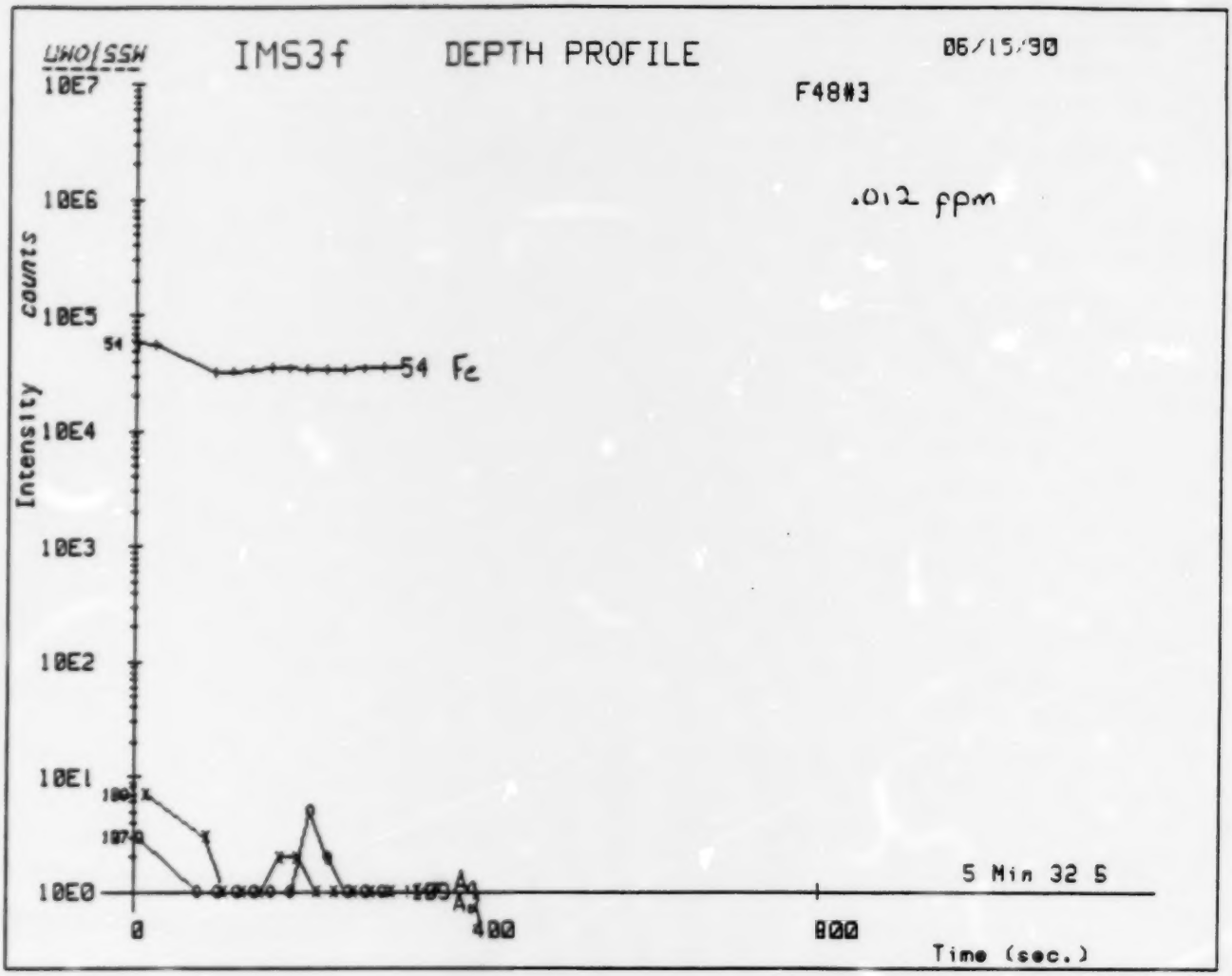
Manual

MASS NUMBER : 54.00 COUNT TIME : .10 OFFSET VOLTAGE : 0.00
M.F.P.: 27023 4

TIME(SEC)	COUNT	TIME(SEC)	COUNT	TIME(SEC)	COUNT	TIME(SEC)	COUNT
3	624	24	2533	69	7997	92	8436
114	8435	137	8809	160	8623	183	9292
205	8494	228	8759	251	8365	273	9864
296	9507	319	9446	342	8932	364	9797
387	9251	410	9390	432	9484	455	9682
478	10005	500	9761	523	9367	546	9845
569	9327	591	9551	614	9412	637	9359

Pyrite

Final Tailings



SAMPLE:F48#3 P4
DATE:06/15/90
PRIMARY IONS : OX -
SECONDARY IONS : +
DEAD TIME: 500.00E-10 sec.

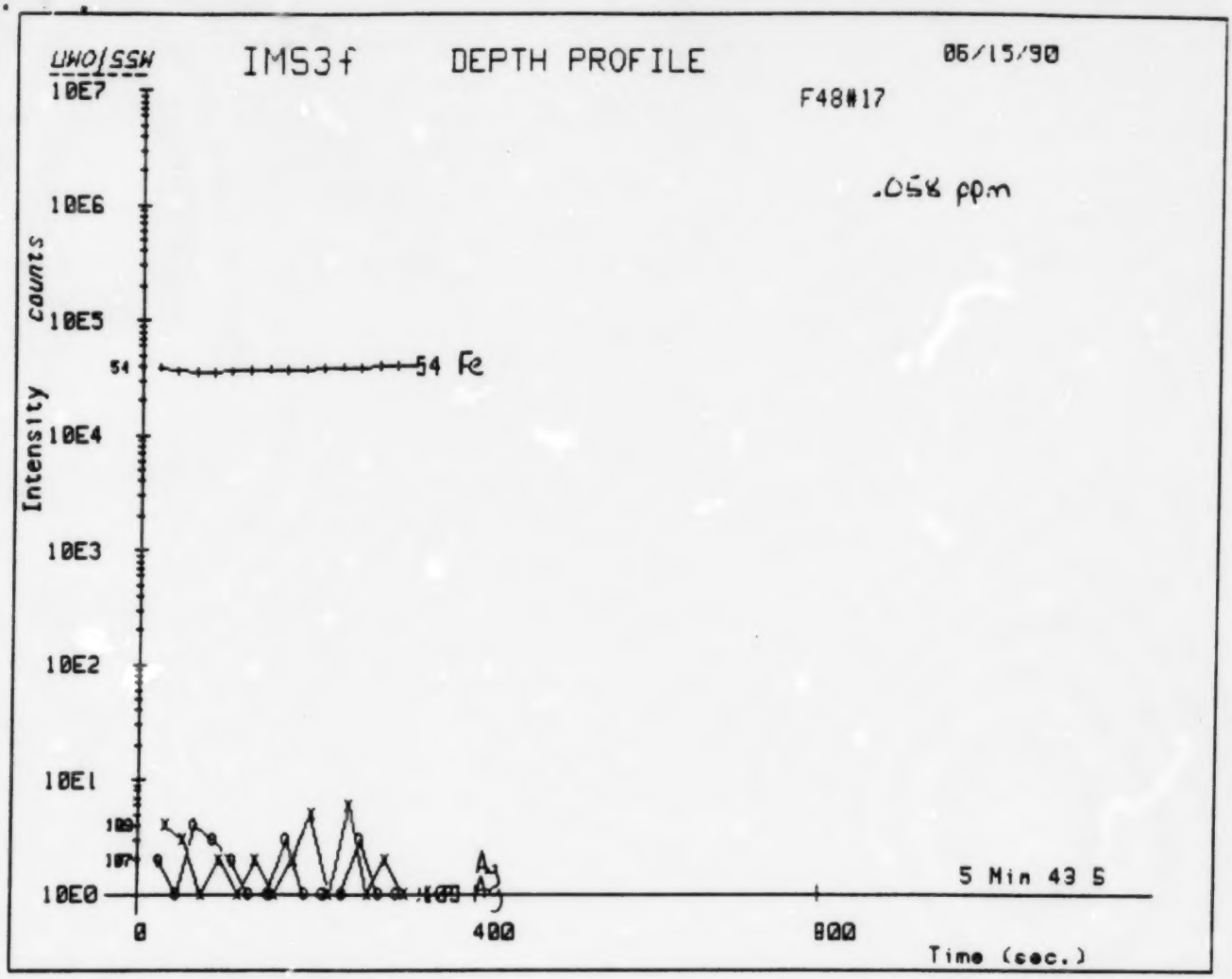
PRIMARY CURRENT : 409 NANO AMP
HIGH VOLTAGE : 12.5 KILOVOLTS
RASTERING : 250 MICRONS
TRANSFER OPTICS : 150 MICRONS
FIELD APERTURE : 1 2 3
CONTRAST APERTURE : 4 3 2 1

Manual

MASS NUMBER : 54.00 COUNT TIME : .10 OFFSET VOLTAGE : 0.00
M.F.P.: 27017 6

TIME(SEC)	COUNT	TIME(SEC)	COUNT	TIME(SEC)	COUNT	TIME(SEC)	COUNT
3	57366	24	56635	95	32359	116	32840
138	34284	160	34775	181	34643	203	33629
225	33679	246	34097	268	34594	290	34906
312	35310	0	0	0	0	0	0

MASS NUMBER : 107.00 COUNT TIME : 3.00 OFFSET VOLTAGE : 0.00



SAMPLE:F48#17 f)
DATE:06/15/90
PRIMARY IONS : OX -
SECONDARY IONS : +
DEAD TIME: 500.00E-10 sec.

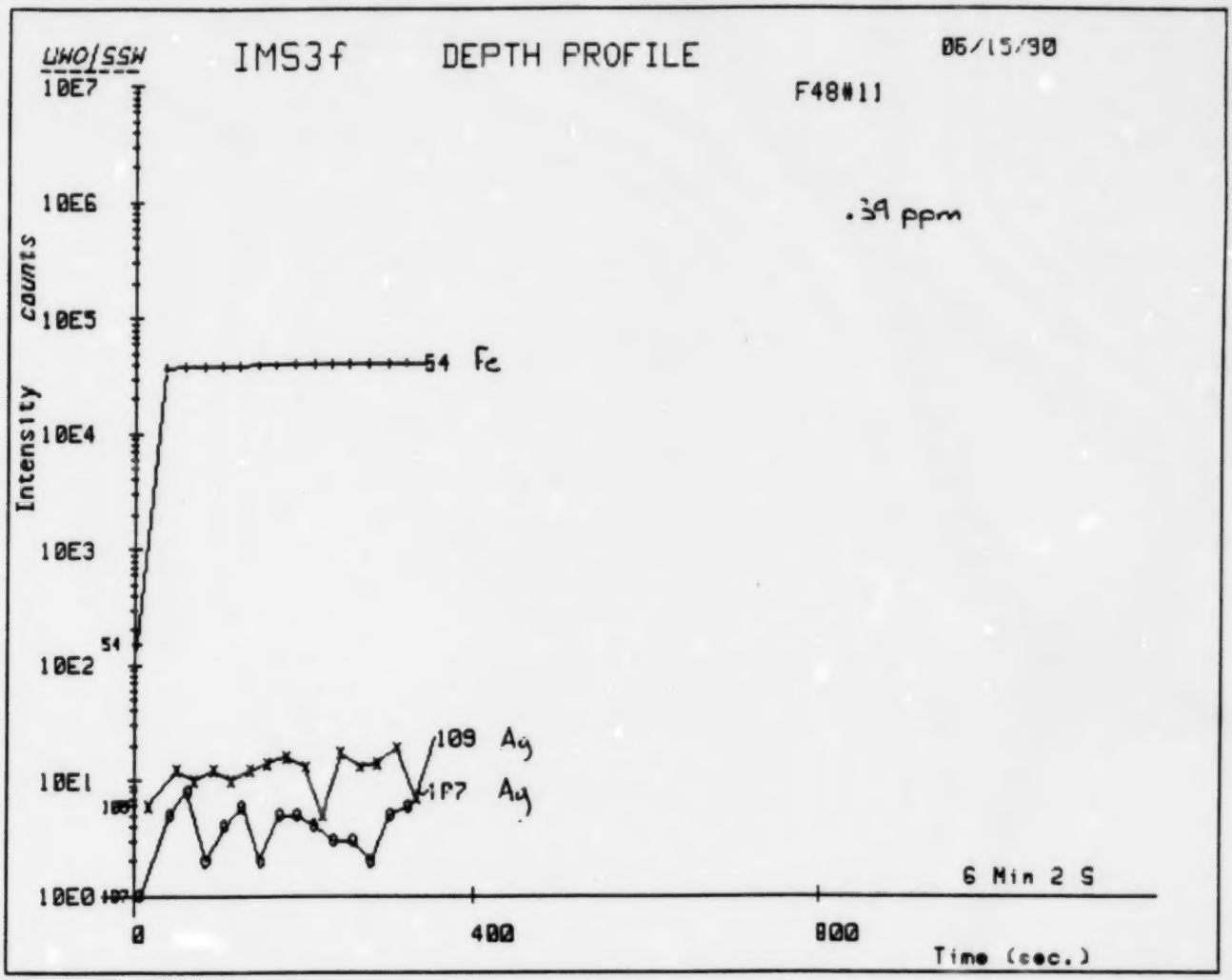
PRIMARY CURRENT : 417 NANO AMP
HIGH VOLTAGE : 12.4 KILOVOLTS
RASTERING : 250 MICRONS
TRANSFER OPTICS : 150 MICRONS
FIELD APERTURE : 1 2 3
CONTRAST APERTURE : 4 3 2 1

Manual

MASS NUMBER : 54.00 COUNT TIME : .10 OFFSET VOLTAGE : 0.00
M.F.P.: 27017 6

TIME(SEC)	COUNT	TIME(SEC)	COUNT	TIME(SEC)	COUNT	TIME(SEC)	COUNT
21	38952	41	36005	63	34944	85	35577
106	36200	128	36664	150	37277	171	37149
193	37402	215	37836	237	38873	258	38420
280	39813	302	39744	323	39872	0	0

MASS NUMBER : 107.00 COUNT TIME : 3.00 OFFSET VOLTAGE : 0.00
M.F.P.: 38456 3



SAMPLE:F48#11
DATE:06/15/90
PRIMARY IONS : OX -
SECONDARY IONS : +
DEAD TIME: 500.00E-10 sec.

PRIMARY CURRENT : 413 NANO AMP
HIGH VOLTAGE : 12.4 KILOVOLTS
RASTERING : 250 MICRONS
TRANSFER OPTICS : 150 MICRONS
FIELD APERTURE : 1 2 3
CONTRAST APERTURE : 4 3 2 1

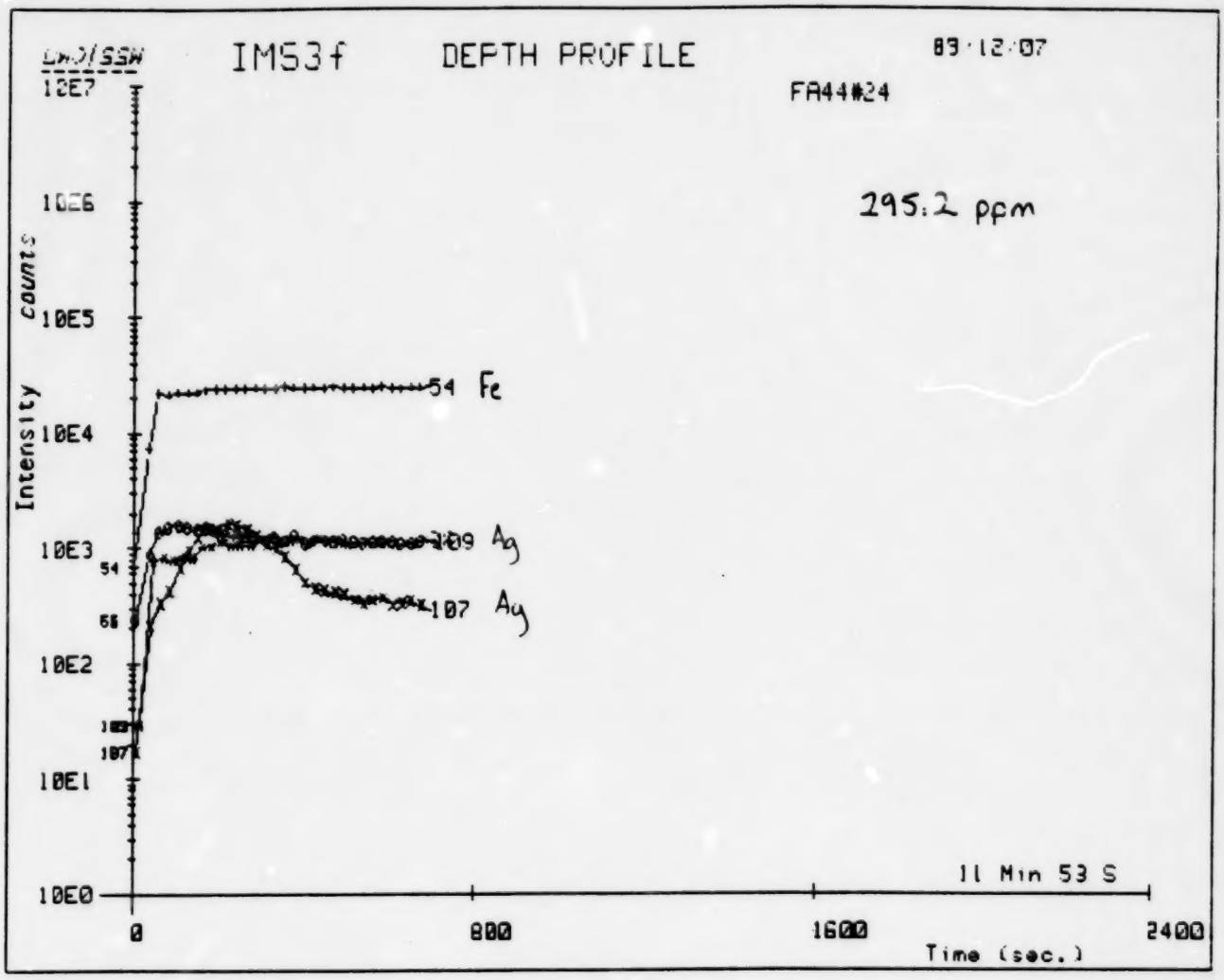
Manual

MASS NUMBER : 54.00 COUNT TIME : .10 OFFSET VOLTAGE : 0.00
M.F.P.: 27017 6

TIME(SEC)	COUNT	TIME(SEC)	COUNT	TIME(SEC)	COUNT	TIME(SEC)	COUNT
3	152	37	37456	59	38731	81	38540
102	38252	124	38531	146	39210	167	39308
189	39713	211	40040	233	40143	254	40052
276	40187	298	40142	320	40476	341	40659

MASS NUMBER : 107.00 COUNT TIME : 3.00 OFFSET VOLTAGE : 0.00

Marcasite
Zn Concentrate and
Final Tailings



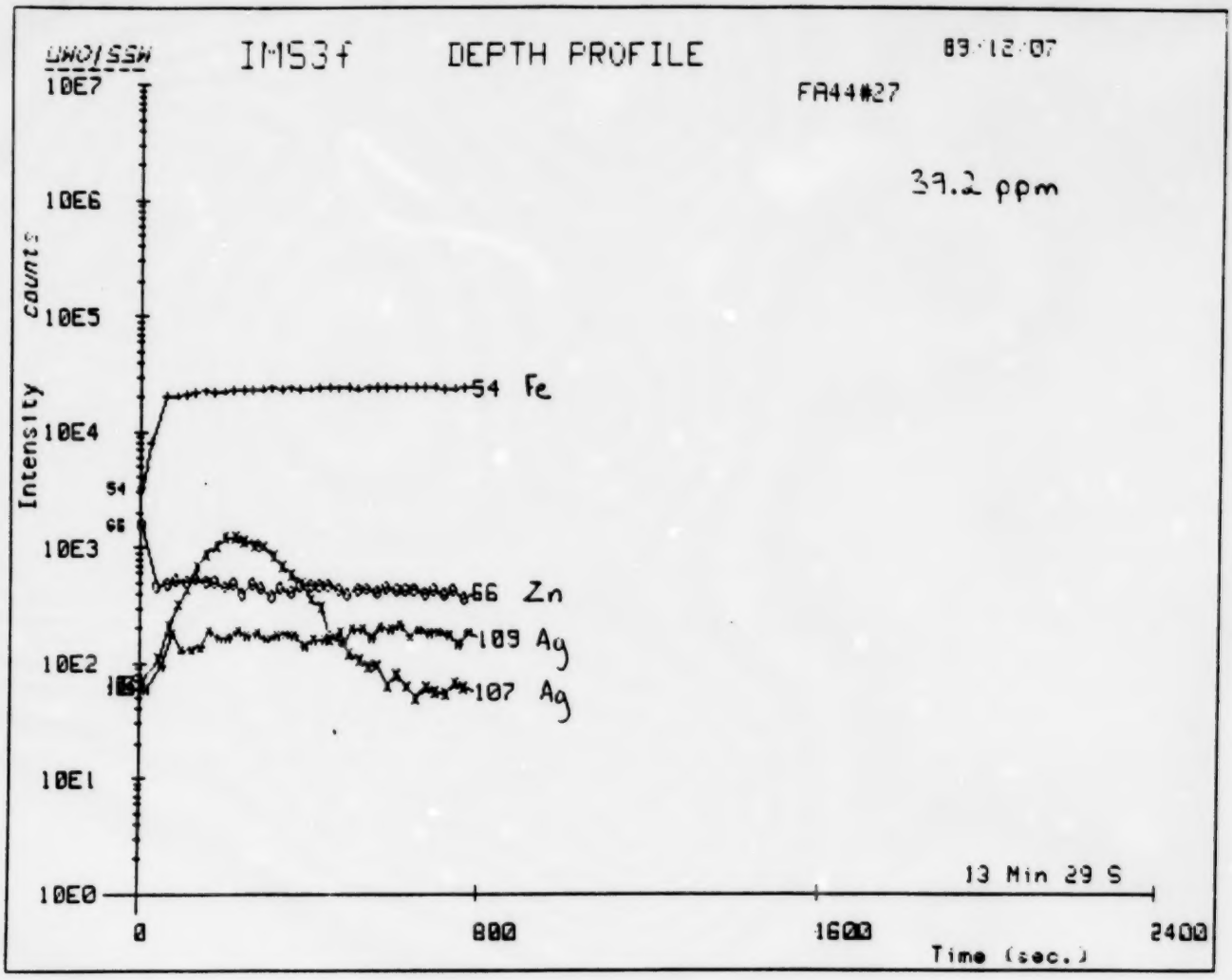
SAMPLE:FA44#24
DATE:89/12/07
PRIMARY IONS : OXYGEN -
SECONDARY IONS : +
DEAD TIME: 500.00E-10 sec.

PRIMARY CURRENT : 497 NANO AMP
HIGH VOLTAGE : 12.6 KILOVOLTS
RASTERING : 250 MICRONS
TRANSFER OPTICS : 150 MICRONS
FIELD APERTURE : 1 2 3
CONTRAST APERTURE : 4 3 2 1

Manual

MASS NUMBER : 54.00 COUNT TIME : .10 OFFSET VOLTAGE : 0.00
M.F.P.: 27030 5

TIME(SEC)	COUNT	TIME(SEC)	COUNT	TIME(SEC)	COUNT	TIME(SEC)	COUNT
3	686	35	7328	58	21917	80	21617
103	22410	126	22508	148	22537	171	23602
194	23914	216	24125	239	24033	262	24221
285	24453	307	24149	330	23799	353	24875
375	24536	398	24217	421	24553	443	24196



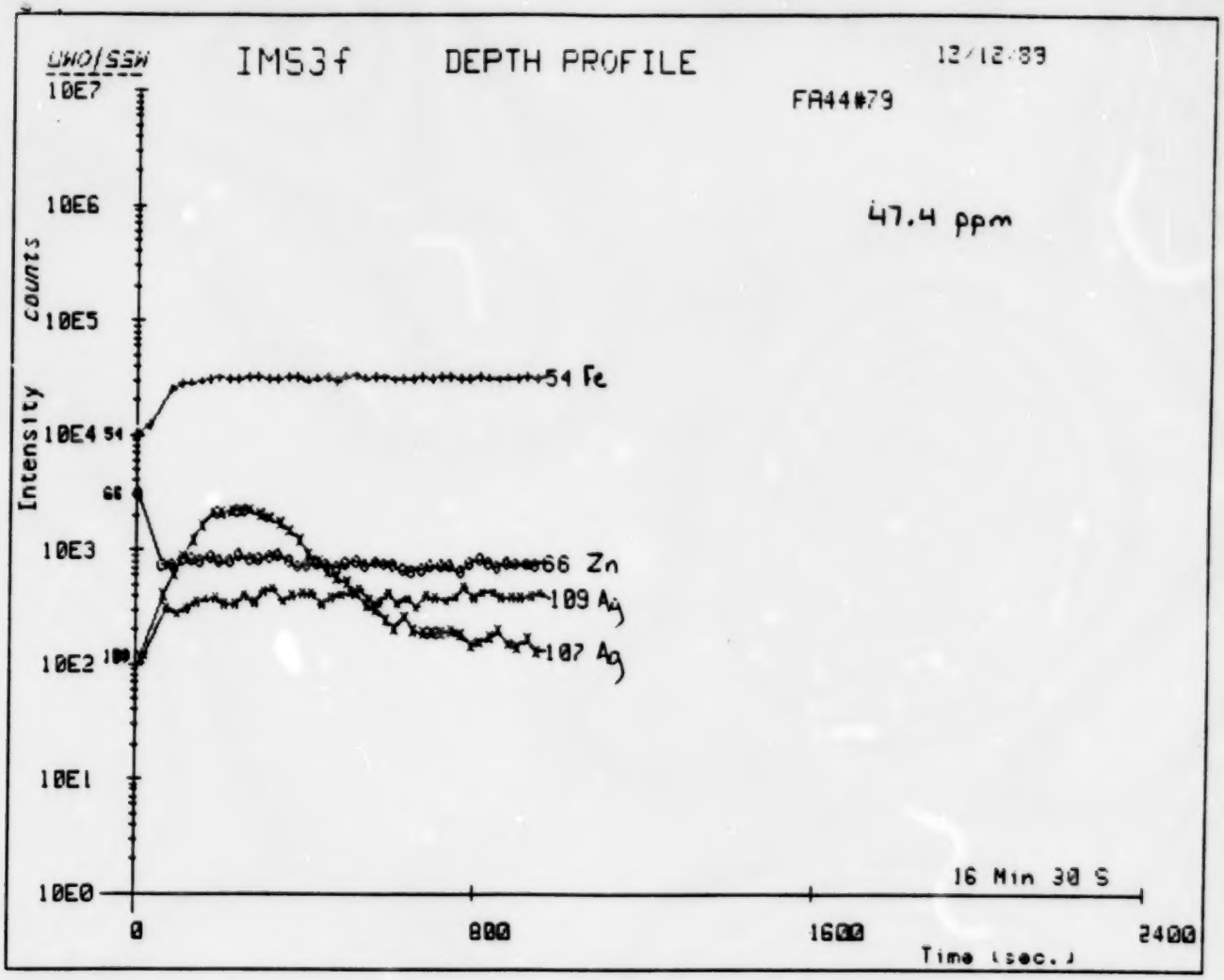
SAMPLE:FA44#27
DATE:89/12/07
PRIMARY IONS : OXYGEN -
SECONDARY IONS : +
DEAD TIME: 500.00E-10 sec.

PRIMARY CURRENT : 482 NANO AMP
HIGH VOLTAGE : 12.6 KILOVOLTS
RASTERING : 250 MICRONS
TRANSFER OPTICS : 150 MICRONS
FIELD APERTURE : 1 2 3
CONTRAST APERTURE : 4 3 2 1

Manual

MASS NUMBER : 54.00 COUNT TIME : .10 OFFSET VOLTAGE : 0.00
M.F.P.: 27030 5

TIME(SEC)	COUNT	TIME(SEC)	COUNT	TIME(SEC)	COUNT	TIME(SEC)	COUNT
4	3261	24	8098	62	20610	85	20735
108	21281	130	21811	153	22745	176	22394
198	22400	221	23035	244	22942	266	23355
289	23507	312	23724	335	22987	357	23697
380	23259	403	23400	425	24068	448	23855
471	23586	493	23993	516	23519	539	23654
561	24047	584	23806	607	23725	629	24318



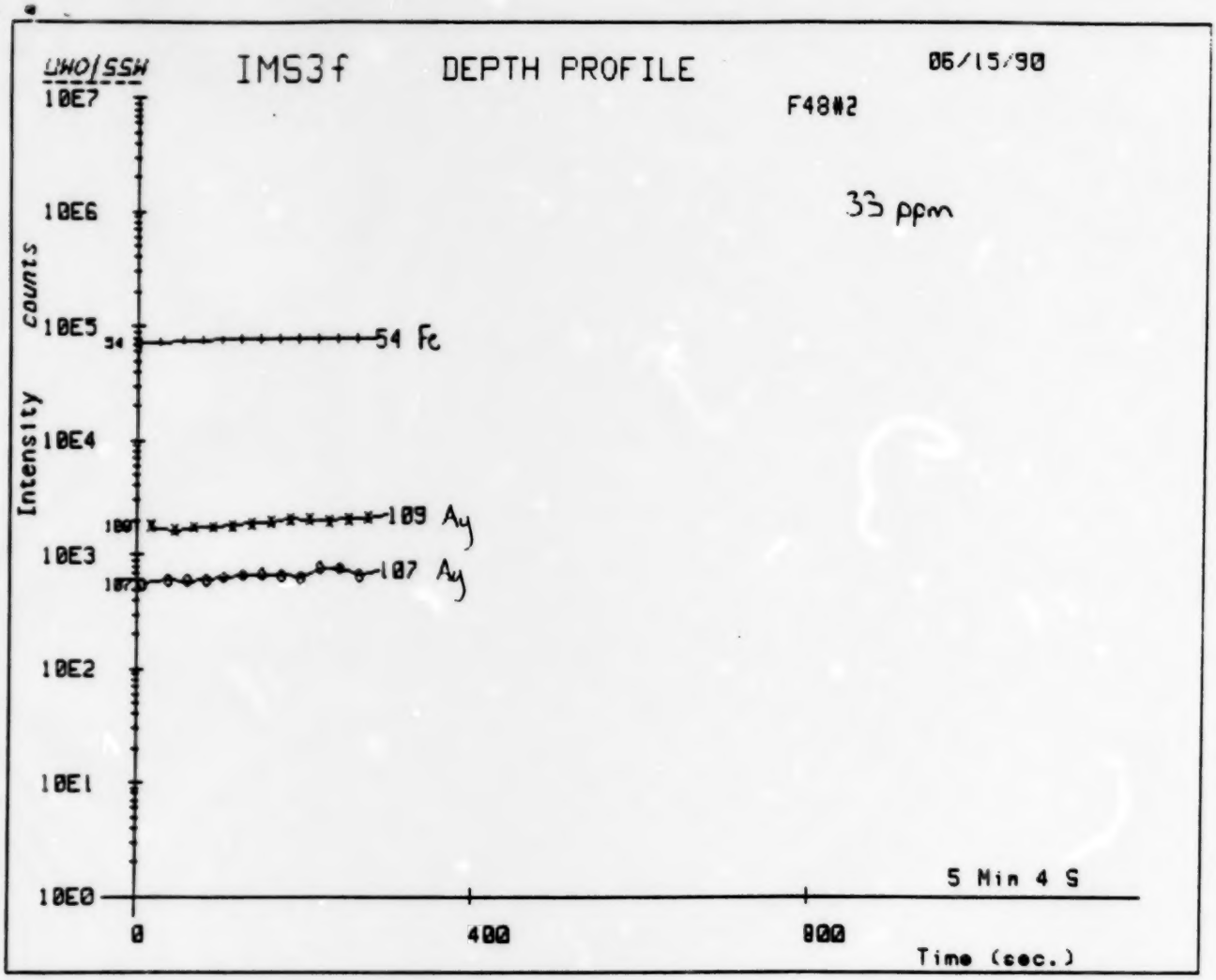
SAMPLE:FA44#79
DATE:12/12/89
PRIMARY IONS : OX -
SECONDARY IONS : +
DEAD TIME: 500.00E-10 sec.

PRIMARY CURRENT : 439 NANO AMP
HIGH VOLTAGE : 12.7 KILOVOLTS
RASTERING : 250 MICRONS
TRANSFER OPTICS : 150 MICRONS
FIELD APERTURE : 1 2 3
CONTRAST APERTURE : 4 3 2 1

Manual

MASS NUMBER : 54.00 COUNT TIME : .10 OFFSET VOLTAGE : 0.00
M.F.P.: 27023 4

TIME(SEC)	COUNT	TIME(SEC)	COUNT	TIME(SEC)	COUNT	TIME(SEC)	COUNT
3	10191	29	12221	84	25607	106	28547
129	28938	152	30168	174	30812	197	31700
220	31389	243	31287	265	32518	288	32745
311	31139	333	31393	356	32312	379	32229
402	30127	424	31597	447	32670	470	30054
492	32858	515	33115	538	31531	561	32398
583	31867	606	30351	629	30644	651	30606
673	32266	697	31230	720	32295	742	31983



SAMPLE:F48#2 mdkC
DATE:06/15/90
PRIMARY IONS : OX -
SECONDARY IONS : +
DEAD TIME: 500.00E-10 sec.

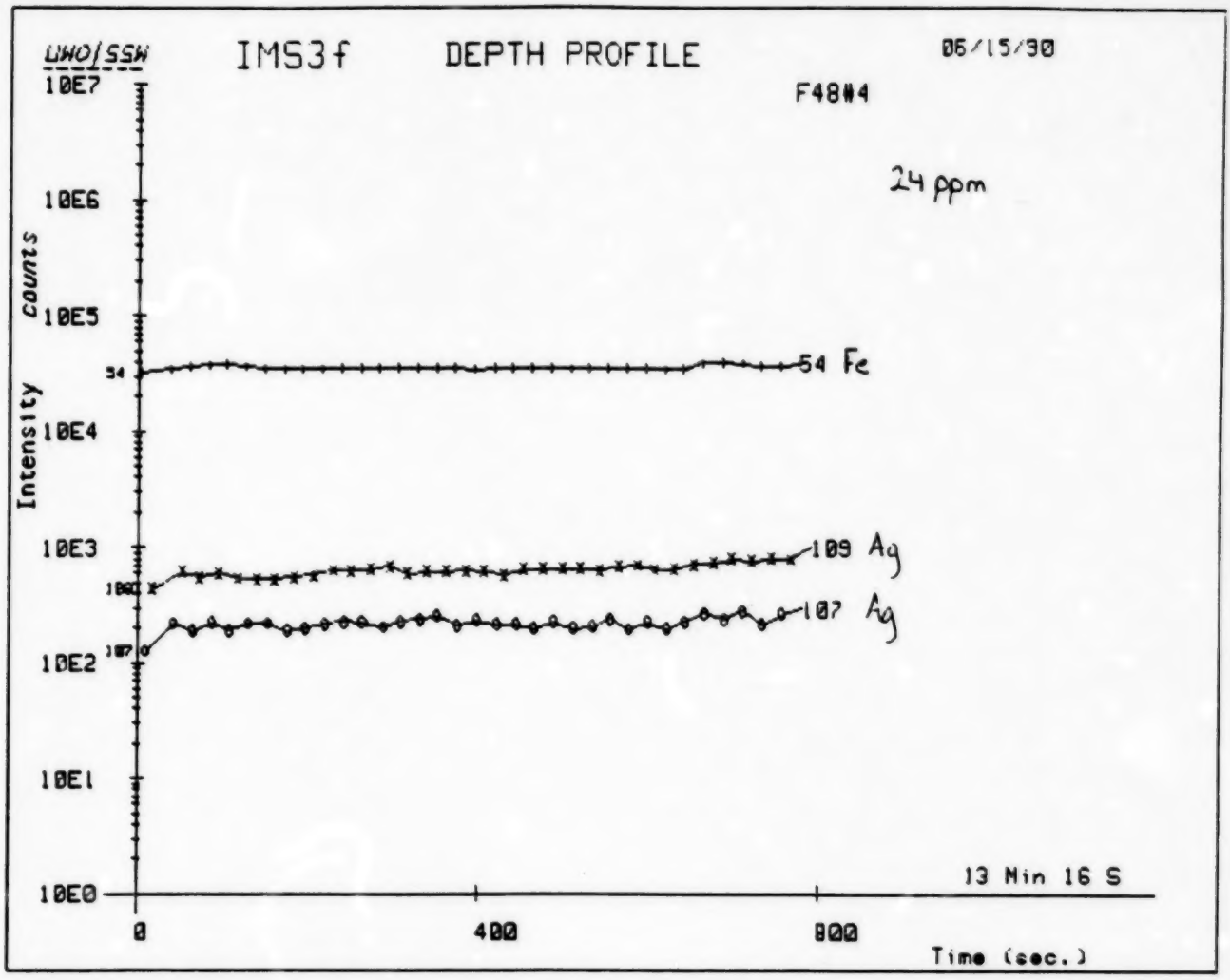
PRIMARY CURRENT : 413 NANO AMP
HIGH VOLTAGE : 12.5 KILOVOLTS
RASTERING : 250 MICRONS
TRANSFER OPTICS : 150 MICRONS
FIELD APERTURE : 1 2 3
CONTRAST APERTURE : 4 3 2 1

Manual

MASS NUMBER : 54.00 COUNT TIME : .10 OFFSET VOLTAGE : 0.00
M.F.P.: 27017 6

TIME(SEC)	COUNT	TIME(SEC)	COUNT	TIME(SEC)	COUNT	TIME(SEC)	COUNT
3	72371	25	73521	55	76586	78	76761
101	77100	124	78688	146	79330	169	78752
192	79167	215	79568	238	78895	260	79568
283	78352	0	0	0	0	0	0

MASS NUMBER : 107.00 COUNT TIME : 3.00 OFFSET VOLTAGE : 0.00
M.F.P.: 38456 3



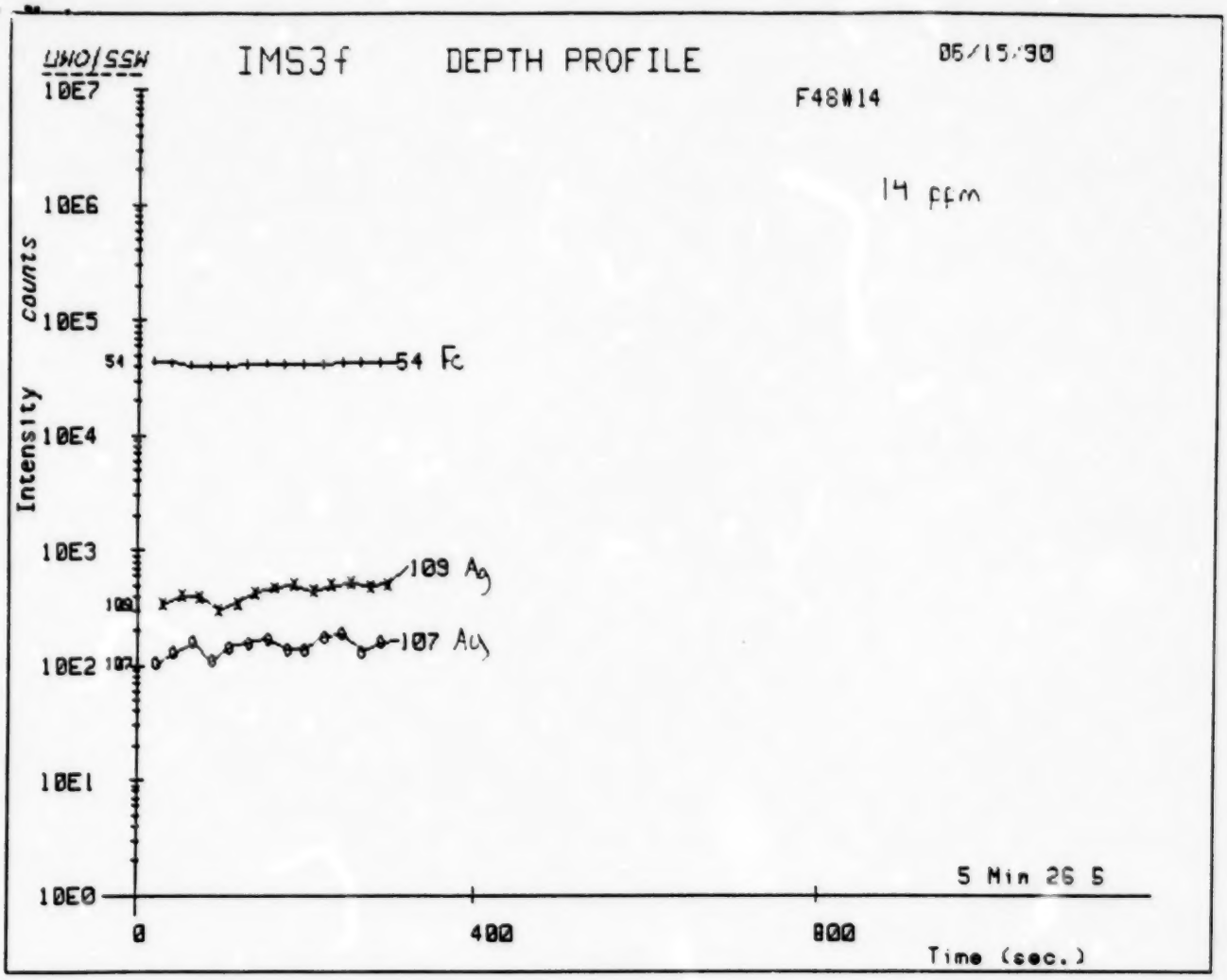
SAMPLE:F48#4 wafer
DATE:06/15/90
PRIMARY IONS : OX -
SECONDARY IONS : +
DEAD TIME: 500.00E-10 sec.

PRIMARY CURRENT : 413 NANO AMP
HIGH VOLTAGE : 12.5 KILOVOLTS
RASTERING : 250 MICRONS
TRANSFER OPTICS : 150 MICRONS
FIELD APERTURE : 1 2 3
CONTRAST APERTURE : 4 3 2 1

Manual

MASS NUMBER : 54.00 COUNT TIME : .10 OFFSET VOLTAGE : 0.00
M.F.P.: 27017 6

TIME(SEC)	COUNT	TIME(SEC)	COUNT	TIME(SEC)	COUNT	TIME(SEC)	COUNT
4	32300	39	34540	61	36977	84	37581
106	37824	128	36182	150	34586	173	34603
195	34471	217	34575	239	34808	262	34767
284	34916	306	35177	329	35299	351	35232
373	35008	396	34366	418	35070	440	34762
462	34853	485	34862	507	34598	529	34974



SAMPLE:F48#14
DATE:06/15/90
PRIMARY IONS : OX -
SECONDARY IONS : +
DEAD TIME: 500.00E-10 sec.

PRIMARY CURRENT : 416 NANO AMP
HIGH VOLTAGE : 12.4 KILOVOLTS
RASTERING : 250 MICRONS
TRANSFER OPTICS : 150 MICRONS
FIELD APERTURE : 1 2 3
CONTRAST APERTURE : 4 3 2 1

Manual

MASS NUMBER : 54.00 COUNT TIME : .10 OFFSET VOLTAGE : 0.00
M.F.P.: 27017 6

TIME(SEC)	COUNT	TIME(SEC)	COUNT	TIME(SEC)	COUNT	TIME(SEC)	COUNT
19	44297	39	42596	61	40559	84	39450
106	40392	128	41249	150	42230	172	42027
194	41695	217	42179	239	43183	261	43528
283	43703	305	44283	0	0	0	0

MASS NUMBER : 107.00 COUNT TIME : 3.00 OFFSET VOLTAGE : 0.00
M.F.P.: 38456 3